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Research for Tomorrow's Agriculture — A Challenge to Engineers *Dr. R. W. Trullinger*

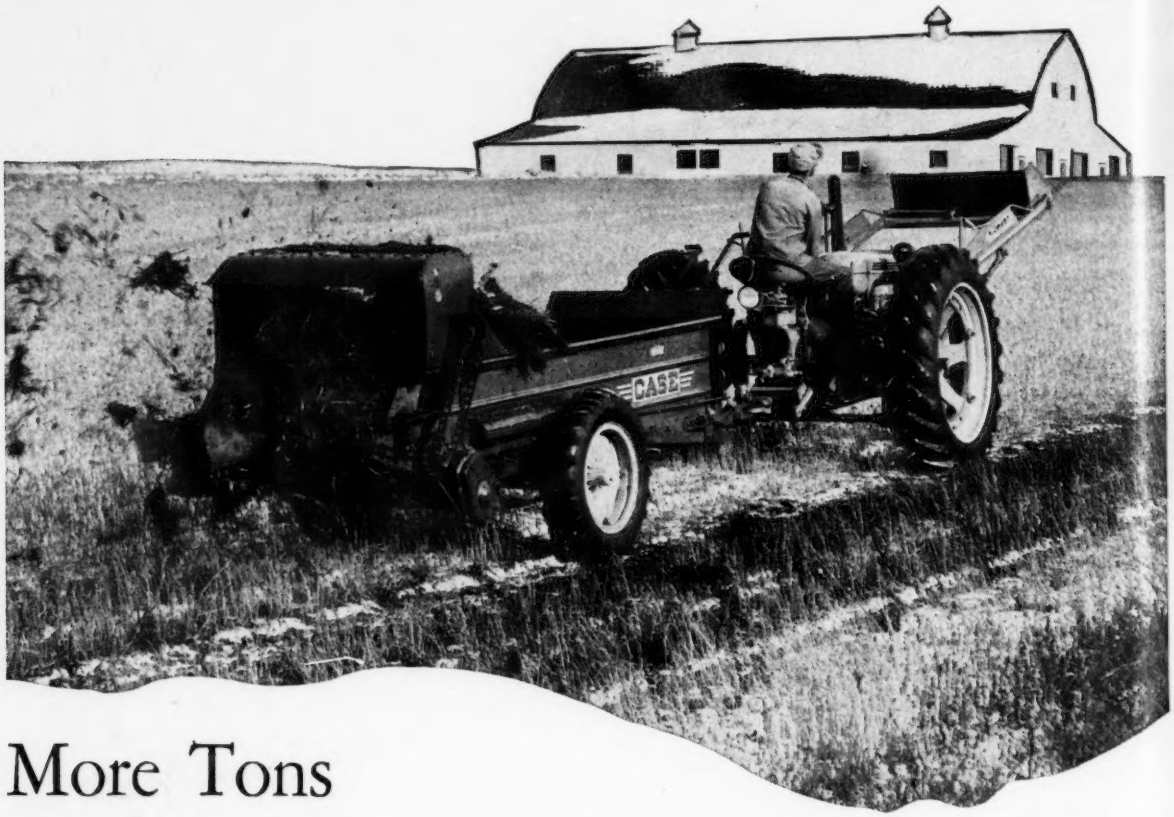
Ventilation of Animal Shelters by Use of Heat Exchangers *Henry Giese, A. A. Ibrahim*

Variable-Speed V-Belt Drives for Farm Machines *E. G. Kimmich, W. Q. Roesler, W. S. Worley*

Principles of Soil Physics in Relation to Tillage *Dr. G. M. Browning*

Application of Fluidization to Conveying Grain *A. D. Longhouse, D. P. Brown et al*

THE JOURNAL OF THE AMERICAN SOCIETY OF AGRICULTURAL ENGINEERS



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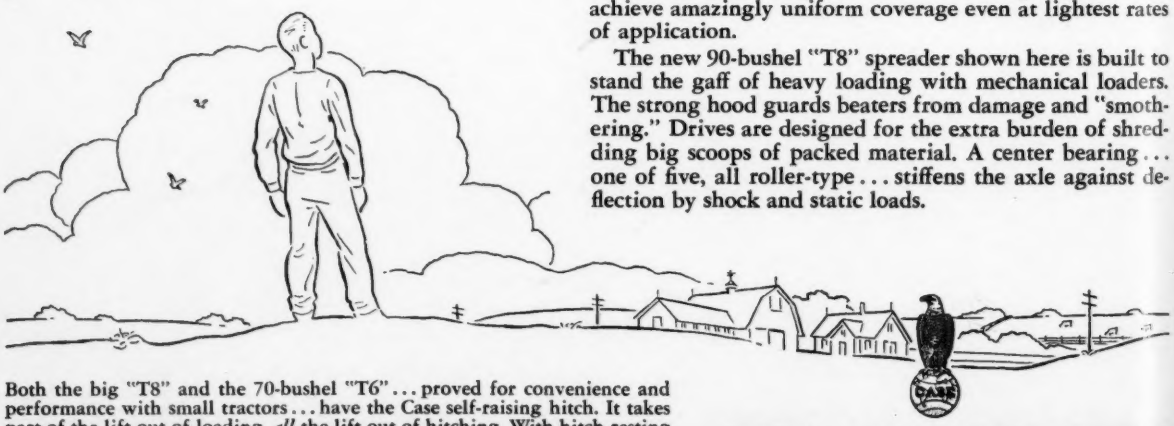

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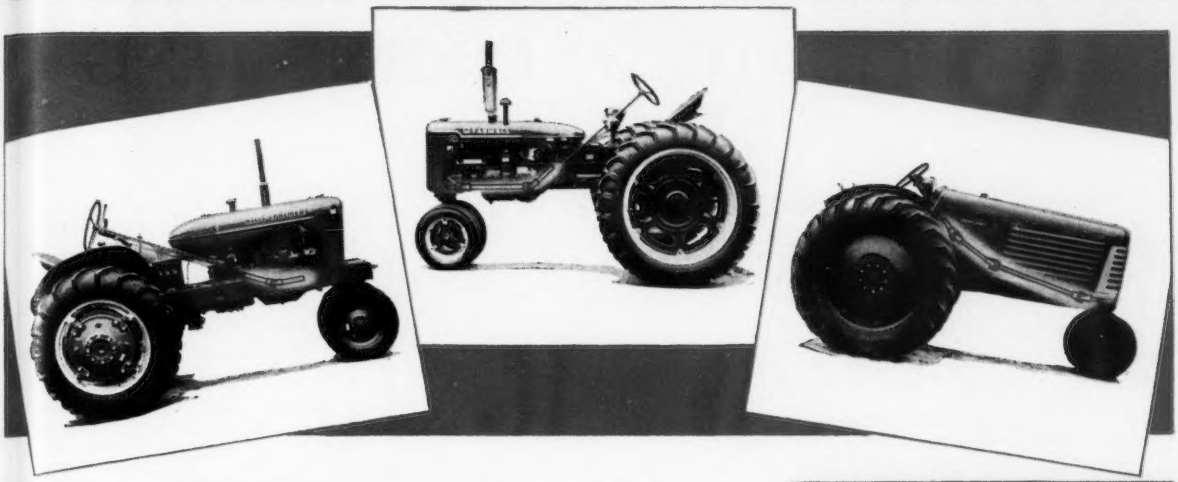

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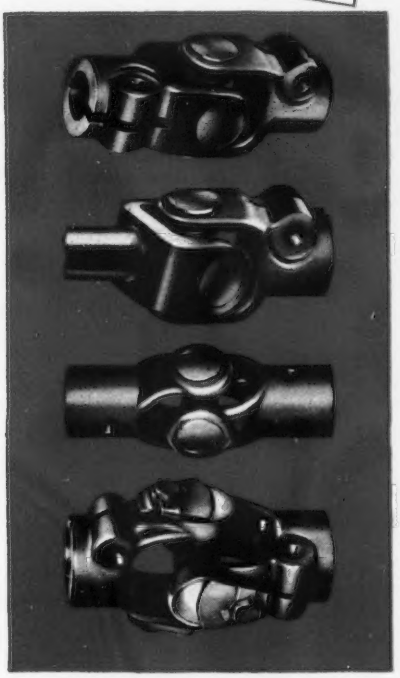

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AGRICULTURAL ENGINEERING

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EDITORIAL

Farm Safety Engineering

WITHOUT the influence of National Farm Safety Week this year (July 23-29) and those of past years, farm accident losses would undoubtedly be considered higher than they now are. But they are far from low enough. Might they not be made significantly lower by more widespread active participation in Farm Safety Week; by some additional effort during that week and throughout the year?

Reduced to its most basic terms, safety involves two factors the individual and his environment. Both are influenced by engineering.

Consider environment. No one can farm in a padded cell, but much can still be done to make the farm environment safer by increased engineering attention to clearances, shielding, footings, contact surfaces, lighting, handholds, stability, ventilation, fire prevention and protection, design to facilitate good housekeeping, automatic alarms, controls, and other safety devices.

Consider the extent to which agricultural engineers might further influence the action of the individual farmer in his environment, in the interest of safety.

Analysis of work methods and development of safe procedures are largely matters of physical factors and relationships in which engineering is a proven sound approach. Environment and methods are closely related. Combinations of equipment and methods can sometimes be developed so that the safe way of performing an operation is also the easiest, simplest, most natural, and most economical way.

Getting a farmer to use an available safe method is another matter. Influencing the actions of a human individual requires something more than a mechanistic approach. While safety education is not exclusively a matter of agricultural engineering, it is something on which agricultural engineers can help because most of you are educators to some extent, have contacts with farmers, have the confidence of many farmers, and are experienced in helping farmers to adopt improved methods.

It is well established that many farm accidents result from failure to practice safety measures already known to one or more of the victims or their immediate families or readily available to them. It is a price they pay for failure to live and to farm as well as they easily could.

This means that safety education, to be effective, must be carried to the point of inducing action — safe action — in emergencies and to forestall emergencies. It means that the inducement must be stronger than provided by mere knowledge, more immediate than the threat of pain, more positive than potential losses, more appealing than logic, more timely than occasional reminders.

Habit is one of the strongest influences governing human action. Dangerous habits are responsible for many serious farm accidents. Replacing dangerous habits with safe habits, and preventing the formation of dangerous habits when an individual is learning an operation new to him, is an important part of safety education. To establish safe habits, safety education must be carried to the point of providing supervised practice.

Getting a person to perform an operation in an approved safe manner at least once is the most difficult and necessary step in establishing a safe habit. Each succeeding repetition will be easier and more natural. Inducing that first practice in an instruction period, contest, inspection, mass demonstration, or by other means is the follow-through which will multiply the effectiveness of all the words and pictures which will be published in the interest of farm safety during the year.

Providing this supervised practice in a variety of operations to millions of farm people will be a big job. It can not be done entirely by agricultural engineers, but you can encourage it, do some of it, and help others to carry on the work. It can be done in the agricultural colleges, in teaching vocational agriculture, in extension projects, by manufacturers representatives, by dealers, and by farm employers and other farmers.

National Farm Safety Week sets the stage and provides the audience for intensive attention to farm safety. The rewards are attractive; the engineering opportunities challenging. It is a time for you to think, plan, talk, and show the way to increased year-round farm safety. Incidentally, attention to farm safety will help to make you more safety conscious in your personal life. In the words of the National Safety Council, "the life you save may be your own" or that of someone in your immediate family.

Production Economies

SMALL savings per acre, ton, bushel, pound, gallon, or other unit of farm production add up to figures significant to individual farmers and the national economy.

A saving in annual operating cost, or an increased gain of only one dollar per acre, for example, will be of considerable importance to the 112,000 farmers in the United States who each farm more than 1000 acres. It will be a substantial item to the more than 173,000 farmers who handle 500 to 1000 acres. In fact, it would be more than pocket money to all of the two million plus farmers who operate more than 100 acres.

A net annual gain of only one dollar per crop acre in the United States would count up to more than $350,000,000 direct gain to our national economy.

A reduction of one cent per gallon in the cost of producing milk would be worth considerably more than $100,000,000 per year to the dairy farmers of this country.

These economies may materialize in savings in labor, seed, fertilizer, feed, fuel, other materials, maintenance or a number of other items. They may develop through increased yield and proportionate decreases in unit costs. Or they may show up through improved quality of farm products, resulting in a wider margin between unit costs and unit selling prices.

It is the sum of individual economies of this order that has amounted to a revolution in the operating efficiency of American agriculture within the past century.

Their contributions to these economies have provided an economically sound basis for the development and expansion of the farm equipment industry, the farm building materials business, irrigation, drainage, soil conservation, and rural electrification.

Technically sound and effective approach to these economies has justified and earned support for the development of agricultural engineering as a specialized branch of the engineering profession.

We mention these rather obvious points because they are sometimes denied; because they may be temporarily overlooked even by agricultural engineers concentrating on highly specialized technical problems, and because they have a bearing on the future of agriculture, its service industries, and agricultural engineering.

Confidence that further economies in farm operations can and will be developed is inspired by consideration of recent progress in improving farm operating efficiency; the research and development work currently directed toward that end, and the current widespread appreciation of remaining problems and opportunities for further economies.

Whether labor and other farm cost items continue to increase, whether farm product prices hold steady or rise or fall, economies in farm operation will continue to be important. A dollar saved in his unit production costs will be a dollar added to the net economic service rendered by the farmer. And economic service rendered is the only real, sound basis for farm prosperity. Industries, agricultural sciences, and agricultural engineers engaged in helping farmers realize specific small unit savings in their production costs will continue to find a satisfying, profitable opportunity to contribute to that prosperity.

HOG-TYING STORM WATER
TO A WHEAT CROP
Pulling four 5-shovel John Deere lister-chisels working 10 inches deep, this Diesel D7 tills 10 acres of wheat land per hour. Outfit is owned by C. T. Peacock, Arriba, Colorado.

Drouth does not bluff C. T. Peacock, Arriba, Colorado—for he has raised wheat crops with his summerfallow system even in dry years, when total failure was general in his area.

Heart of the Peacock system is the use of the heavy-duty lister-chisel of his design. The picture shows Mr. Peacock's "Caterpillar" Diesel D7 Tractor pulling four of the 5-shovel lister-chisels—working the soil 10 inches deep.

Note how rough and cloddy this operation leaves the ground, to resist wind erosion— yet it is opened far below normal plowing depth, to "drink" water like a sponge and prevent loss by run-off. Storm water is literally "hog-tied" in the soil on which it falls!

The lister-chisel operation is preceded by early-spring disking of the stubble and is followed by fast cultivations to keep the fallow weed-free till seeding time. And seeding is done with deep-furrow drills. This method works for C. T. Peacock!

The grain-grower who hitches a successful summerfallow method to the correct size of "Caterpillar" Diesel Tractor commands important advantages. Ample drawbar pull to do his primary tillage extra well. Positive traction, on soft summerfallow to pull extra wide cultivator hitches for speedy moisture-saving weed-control. And on the deep-cushioned seat of this modern Diesel tractor, he farms with those who set the world's economy pace!

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AGRICULTURAL ENGINEERING

VOL. 31 JULY, 1950 No. 7

Research for Tomorrow's Agriculture

By R. W. Trullinger

LIFE FELLOW A.S.A.E.

DURING the 36 years of my membership in the American Society of Agricultural Engineers, and during the 43 years of the Society's existence, we have seen the United States muster the greatest concentration of industrial efficiency ever known. It was natural, as the nation changed from a rural to a highly industrialized civilization, that agriculture should change with it. It is a tribute to the engineers, many of them among the founders of this Society, that agriculture has been able to keep pace, and in some fields even surpass, the efficiency achieved in other fields.

It is typical of the attitude of the American Society of Agricultural Engineers that its program committee should include on its agenda a discussion of "Research for Tomorrow's Agriculture". Progress in agriculture is based on research in the fundamental sciences. Such a discussion is evidence that as engineers the members of this group are concerned with the future of the agricultural industry, what it may be tomorrow and in the years to follow.

Personally, I was a little hesitant to undertake the assignment to address members of ASAE. Forecasting things to come may be a favorite sport with some people in the less precise occupations. But forecasting in the scientific world may be challenged by some as questionable procedure. Forecasting the scientific research programs and possibilities for the agriculture of the future can, therefore, be entered into only with certain qualifications and considerable caution. However, if you will bear with me, I am willing to take a chance. While I cannot hope for universal agreement with my thinking, I can at least hope that some of the ideas I express will stimulate a thoughtful discussion.

Perhaps we had better start with full recognition of the fact that the agricultural industry in the United States is gradually becoming a big food and fiber-production business. American farming has long ceased to be just a way of life. Agriculture is operating on a gradually decreasing number of farm units. Statistics show a decrease of nearly a million farm units since 1935. But there is a considerable increase in the average size of the individual farm unit. This may be attributed to a number of factors and conditions. But the major impelling factor appears to be the need for greater efficiency in the production of larger yields of food and fiber of higher quality. This is in the face of the further fact that fewer people are engaged in farming.

It would appear that large production is here to stay whether we like it or not. The upsurge of efforts to develop better marketing and distribution procedures during the past few years seems to accept the fact that large-volume production is here to stay. Everything is geared for mass production on a big-business scale, and it would be difficult to believe that the agricultural industry of today will voluntarily revert to last-generation methods and practices. Efficiency is not only now of paramount importance in farming, but it may be expected that future years will intensify its need.

As agricultural engineers have often pointed out to their brethren, agriculture is not only a mechanical industry but one in which biology plays a major part. It is, in fact, so dynamic biologically as to permit of relatively little human control. There is only about so much land on which to produce crops and livestock. Improved varieties of crops have been developed, the yields from which are far beyond the yields of similar crops of previous years. Soils have been put under terrific strain in the process and lands have gone out of production for one crop and gone into production for another. Some lands have been abandoned altogether through misuse. Others not previously used have come into production either wisely or unwisely. But the fact remains that we have only a certain amount of agricultural or potentially agricultural land available in the United States. This, in the face of a steadily increasing population, makes one thing sure. Future research must, above all, keep in mind the need to feed and clothe more and more people from a limited over-all acreage. The problems of land use, therefore become paramount. They will call for the best of scientific approaches.

Surpluses and how to dispose of them with a minimum of loss will probably always constitute a problem. History indicates that George Washington, Thomas Jefferson, and other prominent farmers of this country had to struggle with surpluses. Adequate distribution and marketing mechanisms always have been and probably always will be a number one need. Certainly a reasonable part of our research effort will have to be devoted to this need, now and in the future. Such research not only helps prevent loss for farmer-producers, but it serves to get adequate amounts of food and fiber to places where they are needed and where they can be used most effectively. As a people we would much rather see surpluses of food and fiber than to be confronted with terrible shortages of these necessities of life. Many people on this earth, even some within the limits of our continent, frequently go undernourished and ill-clad. I well remember that as a farm boy, big crops meant that we were comfortable and well fed even though the prices of corn, hogs, and beef cattle went down. But crop failures were usually accompanied on a wide front by hunger and misery.

This then leads me to the next point. People in the United States

This is an address delivered at the 43rd annual meeting of the American Society of Agricultural Engineers at Washington, D. C., June, 1950.

The author: R. W. TRULLINGER, chief, Office of Experiment Stations, and assistant administrator of agricultural research, U. S. Department of Agriculture. Dr. Trullinger was the 1941 recipient of the John Deere Medal awarded by the ASAE.

could, without intelligently planned research and more efficient production, be faced with widespread crop failures, in the not too distant future. We are feeding and clothing more people than ever before. Fewer people are working at the job of farming. Our productive resources have been overworked and strained. We are taking all kinds of risks with our resources to accomplish big production. It would be a new and harrowing experience for this great country to be filled with hordes of hungry people struggling for existence. This should never happen. It can be prevented if our powers of deductive reasoning, as these relate to the maintenance and constant development and improvement of our productive resources, are supported and encouraged.

This means we must utilize the latest and most modern scientific principles and techniques. We must devise ways and means, not only to conserve our existing and potential resources such as soil, water, plants, and animals, but also to conserve and maintain these facilities and resources for future production.

We know a lot about the soil. We know that it is a biologically dynamic substance, alive and constantly changing. Our research scientists have identified the ultimate particle size of soil which is considered to be the nucleus of soil energy. Only slow natural processes have been able in the past to release this energy in amounts and at rates dictated by Nature. Probably this has been a good thing when one considers what might happen as a result of excessively heavy fertilization and cultural treatments or other practices if Nature did not put on the brakes. One predominantly agricultural state, for example, produced immense crops during the war ostensibly by use of improved crop varieties and excessively heavy fertilization. After a few years, however, the productive level of the soils of that state began to go down, this in spite of continued heavy fertilization and cultural treatment. What happened? No one knows—yet, except that Nature rebelled. But the soil scientists of the state agricultural experiment station concerned apparently are starting from scratch to get the answer. Farmers must live and pay taxes.

ADVANCED TECHNOLOGIES CREATE NEW PROBLEMS

This is not an unusual occurrence. It is being encountered in many areas and apparently for a multitude of reasons. In my own experience, I learned that a tractor with one bad spark plug can play havoc with the productive level of some soils. Some of our advanced technologies also have created new and difficult problems. We thought we knew all about the soil, how to maintain its fertility and level of productivity for crops. We know enough now to recognize that under normal conditions soil accumulates and stores energy and releases it in crop production through some strange mechanism, the exact nature of which we apparently do not yet know nor do we know how to control it. The phenomenon of photosynthesis involving the manufacturer of a still strange and unknown substance called chlorophyll, apparently essential to plant prosperity, is largely an unopened scientific secret. All of these are factors involved in assuring greater precision in the production of the right kind of food and fiber from the soil, if we can only learn their basic mechanisms and how to manipulate them constructively without destroying them or the basic resources upon which they depend.

We talk glibly about the sun's rays in relation to the total energy needed to grow a food crop. Yet what do we actually know about the basic mechanism involved in utilization of the sun's energy? And how might we improve on such use and thereby possibly conserve our more tangible resources of energy? What do we know about the possible influence of the sun on the ability of rainwater to expedite plant growth? We have a lot of laboratory techniques using elements of the solar spectrum. But what have we accomplished with the sun beyond that? What do we know about cosmic rays? What do we know about many things affecting the relationship between the natural elements and their ways of expression and the sustained productive capacity of the soil for food crops of both plant and animal form? We have developed a lot of improved crops that increase yields. What have these increases in yield done to the total supply of available productive energy and how may we balance income and outgo of energy when we grow a bigger and better crop on the same area of land?

Crops include livestock forage as well as livestock feeds, and also food consumed directly by human beings. In the face of the growing need for more food by a growing population to be produced from the same over-all land area, the unit nutritive value of that food must always be kept in mind. We have learned a lot in recent years about the nutritive value of foods and feeds. We know vaguely at least that through some strange mechanism the nutritive properties of foods and feeds can be influenced by soil management and treatment; and by development of the crops themselves through the application of the principles of fertilization, genetics, and breeding. There are a lot of things that we do not know about these phenomena, but research scientists are finding out a little more every day. The strange substances known as vitamins are increasing in number almost daily through identification by research scientists. Not everyone can afford to buy these essential chemicals in synthetic form at the prices charged by drug stores.

PROGRESS IN DEVELOPING IMPROVED TECHNIQUES

Every food and feed crop is subject to vicious attack by diseases and insects which seem to be increasing in both number and virulence. Virus diseases of food crops offer one of the most baffling types of problems to the research scientist. For a long time research scientists have had to be satisfied with what amounted to circumstantial evidence as to the character and activity of virus diseases of crops. Much progress has been made through the development and use of new and improved techniques. These include, particularly, better aids to vision, such as the electron microscope. So far, however, virus diseases have been overcome mainly through breeding resistant varieties of crops. This takes a long time. How long will it be before some scientist will develop ways and means of treating infected plants, or of preventing disease infestation by treating plants with vaccines or some other effective method? Probably not until a lot more is learned about these things through a type of research in the future which is not now written in the books. Years ago some farsighted scientists dreamed of this possibility and some still are working at it. They or their successors will undoubtedly sometime accomplish the objective. Give them time and encouragement.

We do a lot of spraying to control external diseases of plants and insects attacking them. Sometimes our efforts are successful and sometimes not so successful. A large number of contact materials used to combat bacterial and fungus diseases and insects of food and feed crops are being used. There is a large minus factor in these practices which some time in the future we cannot afford to accept. Research scientists know a lot about insects and parasites of plants. They know that poisons must somehow penetrate to the vital organs of insects in order to effect a kill. They know also that poisons must stick and spread on vital organs to accomplish the objective. Is this not the phenomenon of interfacial attraction in a form most difficult to control? The procedure is complicated when one considers the large number and variety of diseases and insects encountered, and their probably widely varying electrical properties and responses. Is it not reasonable to assume that research scientists may sometime find it desirable to resort to additional scientific principles, involving such things as high-speed sound waves or other vibrations and the like, to destroy some of these pests either through shock or stimulation of respiration and enforced inhalation of poisonous dusts and sprays? The idea is not new. Men who constantly look ahead in science believe that it can be successfully accomplished.

The problems of human and animal nutrition perhaps are not too different. Animals must have enough of the right kind of feed and forage to assure longevity and rapid gain. Humans must be fed to assure normal growth and sustained health. The picture is somewhat the same as regards animal diseases and their relationship to human disorders. I was informed recently by an authority on animal diseases that no less than forty of these diseases may be transmitted in one form or another to humans. Possibly level of nutrition may have a bearing on human susceptibility to animal diseases. So animal diseases assume a double significance in agricultural research including economic loss and the human hazard. There is a *(Continued on page 338)*

Ventilation of Animal Shelters by the Use of Heat Exchangers

By Henry Giese and Amin Aly Ibrahim
FELLOW A.S.A.E. MEMBER A.S.A.E.

THE ventilation of animal shelters has been a continuing problem for many years resulting in considerable research and many publications. Much effort has been directed toward a solution which would be economically feasible as well as provide satisfactory results. Authors of papers on the subject now seem to be in agreement that ventilation should not only improve the purity of stable air and eliminate odors but, perhaps primarily, remove moisture and prevent condensation which may have detrimental effect upon the structural elements. In a poultry house, there is the further problem of keeping the litter dry, thus avoiding frequent change and reducing the cost of litter, the labor of changing it, and the cleaning of eggs.

It has been observed that droppings in the litter contain a valuable protein factor which has a favorable effect upon the growth and livability of chickens. Keeping the litter sufficiently dry to remain in the house a longer period will add a vital health factor.

Fan ventilation has proven superior to natural or gravity ventilation because of the more positive control accomplished. It must be shut off, however, when the stable temperature reaches a predetermined level. This restriction of air circulation causes a rapid rise in the relative humidity of the air within the stable and consequent condensation on walls and ceiling.

The problem of ventilation or air conditioning differs radically in an animal shelter as compared with an artificially heated structure, such as a dwelling. In the latter, cold air entering may have a high relative humidity but, due to lack of capacity, a low absolute humidity. When this air is heated by a furnace giving off no moisture or a limited amount at most, the capacity of the air for moisture is greatly increased, resulting in a comparatively low relative humidity.

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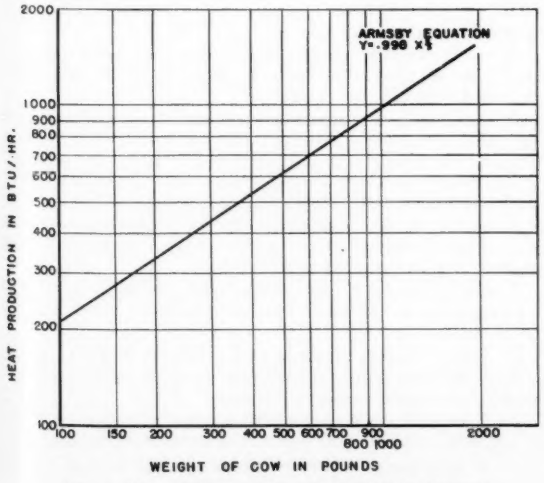


Fig. 1 Heat production of a cow (fasting katabolism)

The situation is quite different in an animal shelter in which the heat is supplied by the animals which give off a large quantity of water in comparison to the heat produced.

In addition to offsetting heat losses through walls and ceiling, the animal heat should be sufficient to vaporize water produced within the stable which cannot readily be disposed of by other means, and heat the circulating air necessary to absorb the moisture and remove it.

It is necessary first to evaluate the heat and moisture production within the stable and also that portion of the moisture which must be removed by circulating air. Unfortunately this is not simple. Investigators do not agree and it is evident that both heat and moisture production vary from animal to animal as well as from time to time. Authors using data furnished by investigators have made different assumptions, resulting in controversial conclusions. We will however attempt to review previous work and to calculate a heat balance for dairy cows and poultry.

The Dairy Cow. The heat production of the cow can be estimated from publications by Armsby(1)* or Kriss(10) (Figs. 1 and 2). In both methods, it is necessary to know the weight of the animal and the amount of dry matter in the daily ration. An average 1250-lb Holstein cow produces about 3,500 Btu per hr.

The unpublished research done recently by Dr. Samuel Brody of the University of Missouri indicates higher values for latent heat production than earlier studies by Forbes, Mitchell and Hamilton (Figs. 3 and 4). Knowing the heat produced, it is possible to calculate the latent heat and the respired moisture. Our experiment indicates that as much as 0.21 lb of water per cow per hour may be evaporated from the urine and feces when the inside temperature is 55 F (Fig. 5).

The Hen. Extensive work by Mitchell and Kelley(12) and Barott and Pringle(3) indicates that the average heat production for a 4-lb hen is 40 Btu per hr. This is considerably lower than suggested by Sammet and Barre(16) but has

* Numbers in parentheses refer to the appended bibliography.

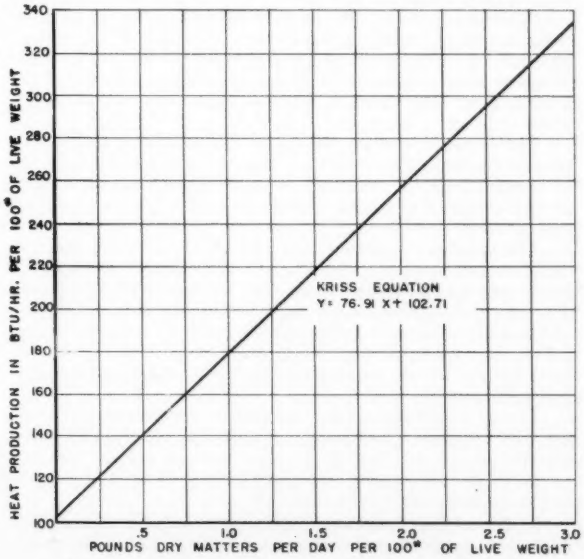


Fig. 2 Heat production of a cow (by dry matter in ration)

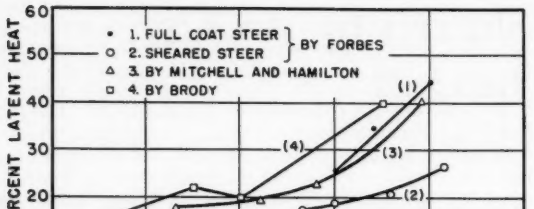


Fig. 3. Per cent heat in latent form for a cow

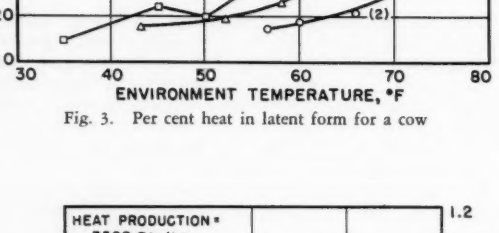


Fig. 4 Moisture production for an average 1250-lb Holstein cow

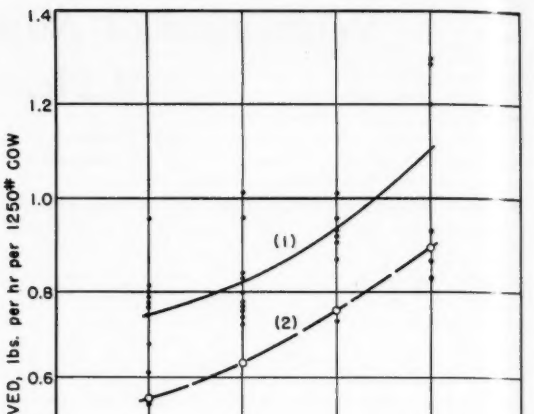

MOISTURE REMOVED, lbs. per hr per 1250# COW
(1) TOTAL MOISTURE REMOVED = 2.133 - 0.0765t + 0.00105t²
(THIS CURVE IS TRUE BETWEEN 40°F AND 55°F)
(2) MOISTURE RESPIRED
STABLE TEMPERATURE, °F

Fig. 5 Moisture removed from stable

been verified in correspondence from Barott who states further that combustion of fat gives over twice as much heat as the combustion of carbohydrates or protein for the same unit weight. For a hen, the latent heat decreases as the environmental temperature falls, but at a temperature of 40 F or below, about 10 per cent of the total heat appears as latent heat in respired moisture. This will amount to about 0.1 lb of moisture per day. Research by Oliver(15) shows that 100 birds laying heavily consume roughly 50 lb of water per day in winter. Approximately 5 lb of water will be removed from the house in the eggs while much of the balance of 45 lb must be taken out from the house. This gives an average of 0.45 lb per day per bird.

White(17) shows that a hen voids 171.7 g of manure (76 per cent moisture) which consists of 41.2 g of dry matter and 130.5 g of water, or 0.3 lb of water per day. The total moisture produced including that of respiration will, therefore, be 0.4 lb per day which is in close agreement with Oliver's work.

The 64.6 per cent or 110.9 g of this manure which is deposited on the litter, contains 26.6 g of dry matter and 84.3 g of moisture. If the moisture content of the litter is limited to 40 per cent, it is necessary to remove 66.55 g, or 0.15 lb per day per bird.

The moisture content of the 35.4 per cent of the manure deposited on dropping boards after 10 weeks of exposure is found to drop from 76 per cent to an average of 67.5 per cent. The relatively small change may be due to reduced evaporation or formation of moisture as a result of organic matter decay. The decay of the manure is a slow process and, therefore, the production of moisture by this method can be considered negligible.

The total moisture to be removed by ventilation is 0.25 lb per day per bird (0.1 lb from respiration and 0.15 lb from excreta.

According to the previous assumptions, analysis of a barn and a poultry house will be made.

1 *Barn.* Fig. 6 shows a typical heat balance in a stable. Part A of the heat produced is used for vaporizing the moisture. Part B is used in warming the circulating air necessary for ventilation. Part C is the heat loss through the building. This last item depends upon the construction of the barn. If AC is the heat loss per cow, per house, per one degree difference between the inside and outside, Part C can be easily calculatd. A glance at $AC = 20$ will show clearly that the inside temperature of a barn cannot be maintained at 50 F with the ordinary methods of ventilation if the outside temperature is below 14 F.

Poultry House. The chart shown in Fig. 7 is similar to that made for the analysis of a barn.

The AC value of a laying house depends upon the type of wall and roof construction and the location of the pen in the house. In a multipen house some pens obviously are more exposed to weather than others, and therefore react differently with regard to ventilation. The value of AC may range from 0.15 in a well-insulated multipen house to 3 in a poorly insulated detached house. The space allowance per bird is also an important consideration.

Fig. 7 shows that the pen temperature of a moderately insulated house ($AC = 0.8$) can be maintained at 35 F when the outside temperature is 24 F.

If these data are essentially correct, it is quite evident that the heat produced by dairy cows or poultry may not be adequate to vaporize the moisture which should be removed by ventilation, heat the necessary quantity of circulating air, and offset heat losses through building walls and ceiling.

In poultry houses particularly, this deficiency has been in a measure taken care of by using litter as an absorbent. Excess moisture is then removed with the litter.

There are perhaps four alternatives available which will facilitate moisture removal by the ventilation system. They are as follows:

1 Direct heating by the use of a furnace and its complementary equipment such as radiators, air ducts, etc., or electric heating coils in the ventilator intakes

2 Chemical absorbents which remove moisture from the air and hence decrease the amount of ventilation air necessary

3 A heat pump which may be employed to cool the air in summer as well as warm it in winter

4 A heat exchanger by meanst of which heat in the exhaust air is transferred to the incoming air. From the charts on heat balance (Figs. 6 and 7) it is apparent that a major portion of the heat produced in the stable is carried out by the ventilating flues. If one could attain perfection in a heat exchanger, he could recover that portion indicated as *B* which represents the heat consumed in warming circulating air. Complete recovery, however, is not necessary to satisfy the problem at hand.

A heat exchanger is basically a means of transferring heat from one fluid to another. In the present concept (Fig. 8), it consists of forcing the incoming and exhaust airs through pipes in such a manner that they are separated by a thin sheet of metal. It is possible to construct the exchanger in such a manner that both airs will be flowing in the same direction or in opposite directions. In the first case, the system is identified as parallel flow while in the latter it is called counter flow. Each system has its advantages.

A year ago Giese and Downing(9) reported on a parallel flow system which Downing had installed in a barn at the Ontario Agricultural College at Guelph, Ontario. In this system, the incoming air passes through a number of small pipes while the exhaust air is forced through the annular spaces between the pipes and an enclosing duct. Being installed in the hay mow, the system was insulated to reduce loss of heat from the exhaust air to the low temperature mow. It has one surface for heat exchange and one for condensation.

The Investigation. In the winter of 1946-47 we installed a multitube heat exchanger in the agricultural engineering laboratory to check its performance as compared with theoretical heat transfer coefficients. The next winter a counter-flow system was built in a poultry house. During the winter 1948-49 a counter-flow system, modified according to results obtained from the previous year, was installed in a dairy barn. Highly satisfactory results were obtained in this barn which, with a 10-ft ceiling, low animal population and poorly insulated walls, has been consistently wet throughout the winter months.

This system was similar to that built by Downing, but differed in that it used counter-flow and also in that the exhaust air was carried through the small pipes and the incoming air through the annular space surrounding them.

This experience suggested other possibilities which will be discussed here. Theoretically and experimentally the counter-flow system results in greater heat transfer than the parallel oow. In the parallel flow system, there is a maximum temperature difference between the incoming and exhaust airs at the point of entrance but a minimum difference at the point of discharge, while in the counter-flow system, the temperature difference is more nearly constant. In the system used at Ames, it is also found that any heat gained from the outside surface of the duct is a loss from the house which must be returned. At the same time, this gained heat will raise the temperature of the cold air so that the difference between the temperatures of this air and that of the exhaust air will be lessened with consequent lowered heat gain. It has also been noticed that insulating the outside duct results in more heat gain from the exhaust air.

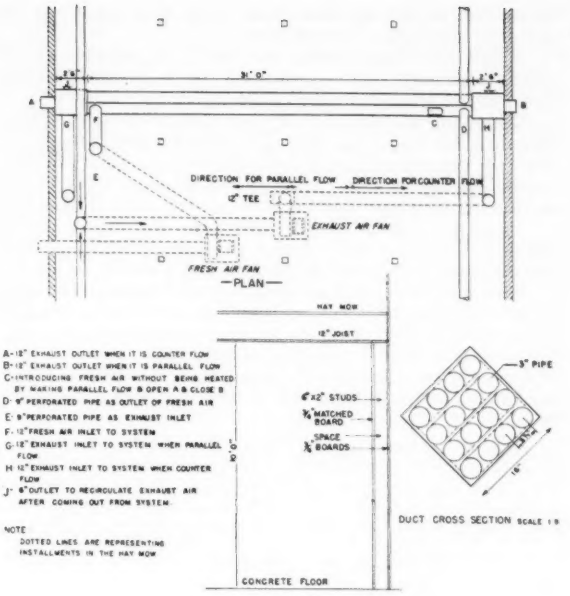

DIRECTION FOR PARALLEL FLOW
DIRECTION FOR COUNTER FLOW
12" TEE
EXHAUST AIR FAN
FRESH AIR FAN
—PLAN—
HAY MOW
12" JOIST
A-12" EXHAUST OUTLET WHEN IT IS COUNTER FLOW
B-12" EXHAUST OUTLET WHEN IT IS PARALLEL FLOW
C-INTRODUCING FRESH AIR WITHOUT BEING HEATED BY WARING PARALLEL FLOW B OPEN A & CLOSE B
D-9" PERFORATED PIPE AS OUTLET OF FRESH AIR
E-9" PERFORATED PIPE AS EXHAUST INLET
F-12" FRESH AIR INLET TO SYSTEM
G-12" EXHAUST INLET TO SYSTEM WHEN PARALLEL FLOW
H-12" EXHAUST INLET TO SYSTEM WHEN COUNTER FLOW
J-9" OUTLET TO RECIRCULATE EXHAUST AIR AFTER COMING OUT FROM SYSTEM.
NOTE
DOTTED LINES ARE REPRESENTING INSTALLMENTS IN THE HAY MOW
6"x2" STUDS
⅜" MATCHED BOARD
SPACE
⅜" BOARDS
3" PIPE
DUCT CROSS SECTION SCALE 1:8
CONCRETE FLOOR
SECTION IN BARN WALL

Fig. 8 Heat exchanger

A second duct encircling the main duct, to replace that used in the hay mow to accomplish a counterflow, the pipe used as exhaust inlet and the trough used to collect the condensate (Fig. 10), provides two surfaces for heat exchange and two for condensation. This type of heat exchanger is called a reversed flow multipass heat exchanger.

The outside duct may either be perforated or slotted to admit entrance of the exhaust air. The incoming air will have the same two surfaces for gaining heat, but all the gain will be from the exhaust air. At the same time the exhaust air, being always in motion when it touches the cold surfaces, will increase the amount of condensation.

The fan motor used for the incoming air should be located at the discharge end so that the heat gained from it will not tend to reduce the temperature difference between the exhaust and incoming airs in the exchanger.

Since several factors affect the shape, length, and number of pipes, the engineer will assume certain factors to be constant and others to be variable. A unit that will serve a certain number of animals and the length of the exchanger will be considered as the first two constant factors. If this can be devised to ac-

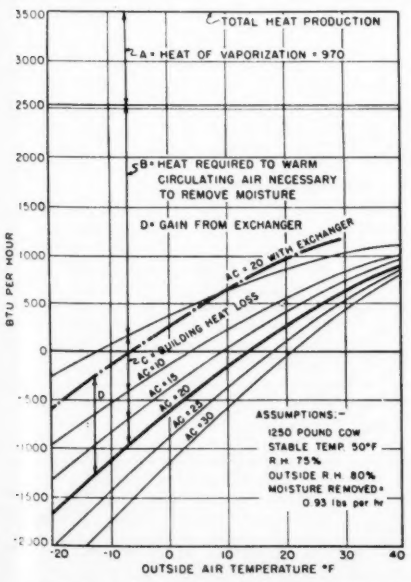
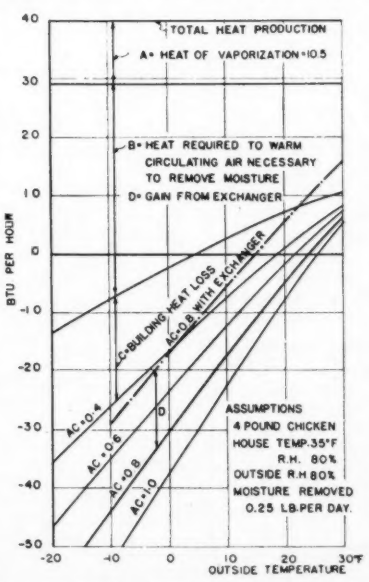


Fig. 6 (*Left*) Dairy stable heat balance • Fig. 7 (*Right*) Laying house heat balance



commodate an average size small barn, more units can be added to take care of larger barns.

A unit 30 ft long serving 18 cows in a barn 34 ft wide will be considered here as a standard for dairy barn, and one 35 ft long to serve a poultry house sheltering 400 birds.

Decreasing the diameter of pipes results in more surface area than for larger diameter pipes for the same velocity of flow. On the other hand, if the surface and number of inlets and outlets are increased, more power is needed to move the air through the pipes. For the same number of pipes of different diameters, the smaller the diameter, the higher is the velocity. The higher the velocity, the higher is the heat gain and the power consumed to move the air.

The total cost of 10,000 Btu is expected to be 12 per cent higher if we use fourteen 3-in pipes instead of thirty-two 2-in pipes, but the running expense is expected to be 70 per cent for the former with respect to the latter. A fourteen 3-in pipe exchanger is recommended for a barn for ease of construction and upkeep and a fourteen 2-in pipe exchanger for a poultry house.

Heat Exchanger Design. Coefficients of heat transfer can be obtained by established formulas concerning conduction, convection and radiation. A simple group of curves (Fig. 9) will give the coefficient of heat transfer if the diameter, velocity and average temperature of flowing air are known.

$$H = M(\Delta h) \qquad = AU\ \theta m\ F \qquad [1]$$

where M = mass of air

Δh = change in enthalpy of air

if t_1, T_1 = inlet and outlet temperature of exhaust air

t_2, T_2 = inlet and outlet temperature of exhaust air

A = surface area of heat transfer

U = heat transfer coefficient

θm = log mean temperature difference for counterflow

$$= \frac{(T_2 - t_1) - (t_2 - T_1)}{\log_e \dfrac{T_2 - t_1}{t_2 - T_1}}$$

F = factor for a multipass exchanger and can be obtained from any heat transfer book.

Knowing the coefficient of heat transfer and the temperature of inlets, the temperature of outlets can be assumed and the problem solved to fit equation [1].

A group of curves can be obtained (Fig. 10) from which a suggested form of the equation of performance of exchanger and its solution can be made:

$$H = k_1(t_i - t_o) + (k_2\ V\ (t_i - t_o)$$

where t_i = inside temperature; t_o = outside temperature; V = volume of air (cu ft).

Referring to the heat balance charts (Figs. 6 and 7), it will be observed that the temperature in the barn described can, by the use of a heat exchanger, be kept at 50 F when the outside temperature drops to –6 F. If the outside temperature falls to –20 F the inside will stay above freezing.

Comparable benefits are a so attainable in a poultry house.

It is undesirable to expect the operator to change the air flow with changes in outside temperatures and almost certain that he will open some of the doors or windows when the outside temperature is above freezing. A four-step regulator valve will reduce the labor needed for managing the exchanger:

1 Air flow required when outside temperature is 20 F or above is 70,000 cu ft per hr for 18 cows

2 Air flow will be 50,000 cu ft per hr for 18 cows when the outside temperature is between 20 F and 0 F

3 Air flow will be 40,000 cu ft per hr when the outside temperature is between 0 F and –20 F

4 Below –20 F, the system circulates 30,000 cu ft per hr for 18 cows.

TABLE 1 - TEMPERATURES, AIR CIRCULATION AND HEAT BALANCE IN DAIRY BARN AND POULTRY HOUSE

outside temp.	inside temp.	air cu/ft/hr	heat losses evap	heat losses ventil	heat losses bldg	heat losses tot.	heat sources animal	heat sources exch	heat sources tot.
18-cow dairy barn, assumed infiltration 5500 cu/ft/hr									
30	61	75500	1400	2500	620	4520	3500	1100	4600
20	59	55500	1350	2400	780	4530	3500	1030	4530
10	55	55500	960	2810	900	4670	3500	1180	4680
0	45	55500	835	2880	900	4615	3500	1180	4680
-10	42	45500	825	2780	1040	4645	3500	1130	4630
-20	32	45500	730	2840	1040	4610	3500	1130	4630
400-bird poultry house, assumed infiltration 4000 cu/ft/hr									
30	50	24000	11.5	22.5	16.0	50.0	40.0	11.5	51.5
25	48	18000	11.5	19.0	18.5	49.0	40.0	9.5	49.5
20	43	18000	11.0	19.0	18.5	48.5	40.0	9.5	49.5
10	33	18000	10.0	19.0	18.5	47.5	40.0	9.5	49.5
5	31	14000	9.5	17.5	21.0	48.0	40.0	8.0	48.0
0	26	14000	9.0	17.5	21.0	47.5	40.0	8.0	48.0

AC assumed at 20 for dairy barn and 8 for poultry house

Table 1 shows the balanced temperatures in the barn assuming infiltration to be 5,500 cu ft per hr for a moderate barn and 10-mph wind.

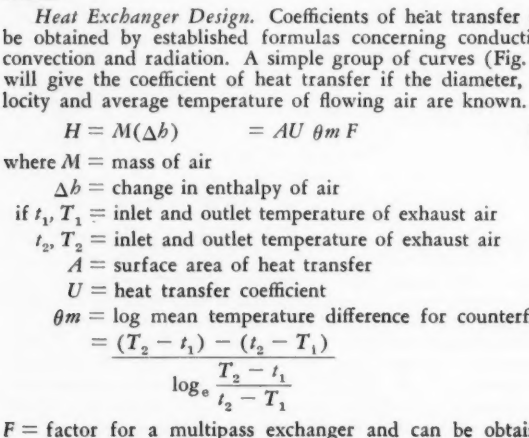


Fig. 9 Coefficient of heat transfer for forced convection of air

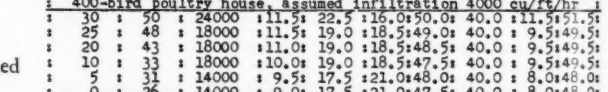


Fig. 10 Performance of heat exchanger for a barn of 18 cows

Since the rate of poultry heat production is practically constant for a given rate of feed consumption, it is evident that inside temperature must vary to some extent with outside temperatures. The variation in indoor temperature can be modified in relation to outdoor temperature, however, by adjusting the rate of ventilation.

For operating the heat exchanger, a four-step valve is again suggested:

1 Below 20,000 cu ft per hr for 400 chickens if the outside temperature is above 30 F

2 Below 14,000 cu ft per hr if the outside temperature is between 30 F and 10 F, a common prevailing condition in winter

3 Below 10,000 cu ft per hr if outside temperature drops down to zero

4 Below 6,000 cu ft per hr in below-zero weather just for circulating the air in the house. This condition, however, does not usually prevail for long intervals.

Table 1 shows also the balanced temperatures in the poultry house, assuming an infiltration of 4,000 cu ft per hr.

Due to the fact that condensation increases the surface coefficient and liberates heat, it has been found that actual heat transfer may be considerably greater than that calculated, particularly when the temperature of the incoming air is low. This situation is favorable to the use of a heat exchanger.

SUMMARY

The heat exchanger offers possibilities in improved ventilation which will eliminate condensation difficulties and keep shelter temperatures at desirable levels. Installations in a dairy barn and poultry house at the Iowa State College have given surprisingly satisfactory results.

The influence was easily seen in the cold waves when better and similar structures were compared to the ones that had this equipment. One day when it was –18 F outside, the old barn with its 10-ft ceiling equipped with this exchanger was as warm and in better condition than a well-built barn with a low ceiling, more live weight per unit area and ventilated by thermostatically controlled fans.

In a theoretical analysis, a barn whose inside temperature level cannot be maintained at 50 F if the outside temperature is below 14 F can, by the use of a heat exchanger, be kept at the same level when the outside temperature drops to –6 F.

BIBLIOGRAPHY

1 Armsby, H. P. and Kriss, M.; Some Fundamentals of Stable Ventilation. *Jour. of Agr. Research,* vol. 21:343-368 (1921).

2 Ashby, W.: Functional Requirements in Designing Laying Houses for Poultry. USDA Circular No. 738 (1945).

3 Barott, H. G. and Pringle, E. M.: Energy and Gaseous Metabolism of the Chicken From Hatch to Maturity as Affected by Temperature. *Jour. Nutr.* vol. 31:35-50 (1946).

4 ..... Personal correspondence. USDA Bureau of Animal Industry, Agricultural Research Center, Beltsville, Maryland.

5 Brody, S.: Bioenergetics and Growth. Reinhold Pub. Corp. (1945).

6 ..... Personal correspondence. University of Missouri, Columbia, Missouri.

7 Brown, A. I. and Marco, S. M.: Introduction to Heat Transfer. 1st ed. McGraw-Hill (1942).

8 Clyde, A. W.: Barn Ventilation with Electric Fans. AGRICULTURAL ENGINEERING, vol. 12:9-14 (1930).

9 Giese, Henry and Downing, C. G. E.: Application of Heat Exchangers to Dairy Barn Ventilation. AGRICULTURAL ENGINEERING, vol. 31:167-70, 174 (1950).

10 Kriss, M.: Quantitative Relations of the Dry Matter of the Food Consumed. The Heat Production, the Gaseous Outgo and the Insensible Loss in Body Weight of Cattle. *Jour. Agr. Research,* vol. 40:283-95 (1930).

11 ..... Insensible Loss in Body Weight of Cattle. *Jour. of Agr. Research,* vol. 40:271-81 (1930).

12 Mitchell, H. H. and Kelley, M. A. R.: Estimated Data on the Energy, Gaseous and Water Metabolism of Poultry for Use in Planning the Ventilation of Poultry Houses. *Jour. of Agr. Research,* vol 47:735-48 (1933).

13 Mitchell, H. H. and Hamilton, T. S.: Estimation of Heat Production From the Insensible Loss in Body Weight. *Jour. Agr. Research,* vol. 52:837-54 (1936).

14 McAdams, W. H.: Heat Transmission. McGraw-Hill Co., New York (1933).

15 Oliver, J. H.: Personal correspondence. General Electric Co., Schenectady, N. Y.

16 Sammet, L. L. and Barre, H. J.: Air Flow in Poultry House Ventilation. AGRICULTURAL ENGINEERING, vol. 30:331-35 (1949).

17 White, J.: Production and Value of Poultry Manure. Pennsylvania State College, School of Agr. Bull 469 (1944).

Research for Tomorrow's Agriculture

(Continued from page 328)

lot of evidence, much of which is somewhat circumstantial and some fairly well substantiated by scientific fact, that there are relationships between the nutrition of humans and animals and the incidence of diseases among them. It is shocking, however, how little we really know about these diseases, their occurrence, transmission, and the like. We see a lot of baffling problems arise in connection with efforts to unravel the mystery of such economically important diseases as lymphomatosis of poultry. Future developments in scientific research will sooner or later find the answer.

We are now resorting to all sorts of practices and procedures in efforts to control diseases of animals which may also affect humans. The antibiotic approach is not new and remarkable progress has been made. However, with progress comes new problems. It appears, for example, that some of the more powerful and active antibiotics when administered for disease control may cause metabolic upsets. Some of these upsets are good and some are not so good depending on what physiological mechanism has been modified. These are questions which must be answered by scientific research. The use of hormone materials to stimulate growth and gain in meat animals and poultry is in the same general category. Evidence of an influence of these materials when implanted into animals is available. The basic mechanism and how to control it for the good of all concerned, including particularly the consumer of meat, milk, eggs, etc., must be elucidated by science before it can become an accepted and safe practice.

Some people raise questions about what they choose to term the proper relationship between fundamental or basic research and applied research. I take the stand, disputed by many, that all research is basic or else it is not true research. I firmly believe that future agricultural research will bear this out. Perhaps in the earlier years of agricultural research considerable effort was devoted to superficial experimentation which did not always result in the establishment of permanent scientifically sound facts. But in more recent years, and particularly since agriculture has become a big business, operating with business methods, agricultural research agencies have had of necessity to employ the best scientifically trained minds and the most modern of scientific principles and techniques. This has been in full recognition of the need for doing in research everything required to solve the problems of agriculture as they are encountered. This will be intensified as the agricultural situation in this country becomes more acute under increased population pressure.

The agricultural research scientist of today must therefore be equipped by training and experience to cope with any and all scientific emergencies as they arise in his part of the field of agriculture. He must also be schooled in the elements of cooperative research because the broad problems of large-scale, mechanized agriculture rarely can be solved by a single research department. This situation is becoming daily more evident. Broad and thorough training in the basic sciences of mathematics, physics, chemistry, thermodynamics, etc., seems to be as important in one segment of agriculture as in another. I was quite impressed by the remark of a former president of this Society, a leader in research and teaching in agricultural engineering for a generation, when he said, "We have just one science." How true this statement is when one delves deeply into the character of the problems facing agriculture today and tomorrow.

To you agricultural engineers I can say with certainty that there is no recognized limit to the knowledge of science and advanced scientific instrumentation which you must possess to cope fully with your part of the *(Continued on page 340)*

Variable-Speed V-Belt Drives for Farm Machines

By E. G. Kimmich and W. Q. Roesler
ASSOCIATE A.S.A.E.

THE V-belt drive has been found to be particularly adaptable for power transmission purposes on farm machinery, as evidenced by their widespread use in the past dozen years or so. It is adaptable to this type of machinery because of its inherent ability to be adequately positive in its power transmission, and still cushion the machine parts under shock or breakdown loads. It was found that crops harvested with a combine required widely varying cylinder speeds for best results. Some designers were also convinced that it was necessary to have a method of speed transmission to the cylinder which would be variable in very small increments of rpm (revolutions per minute), so that all degrees of crop conditions could be satisfactorily met. Into this requirement, the variable-speed V-belt drive fitted perfectly.

With the advent of the self-propelled combine came further use of the variable-speed V-belt drive, as a means of transmitting power to the wheels for ground locomotion. Essentially these so-called traction drives are similar to the cylinder belt drives, in that they provide infinitely variable speed change within the limits of the sheave design. These two applications, cylinder drives and traction drives, are the two important applications for variable-speed drives in the farm implement industry.

Adjustable-speed belt drives include many variations of the idea. The simplest form, is of course, accomplished by changing sheaves, and by interchanging them from one shaft to the other, an extremely wide speed range is obtained. Such drives may use the conventional sizes of V belts and grooves, such as HA to HE cross sections in the proposed ASAE agricultural V-belt standard, and present no special problems other than providing for the occasional severe overloads encountered.

A less expensive design uses split pulleys with filler plates or shims which may be removed from one and put into the other pulley. To get enough speed range the groove angle should be 26 deg as recommended in the standard, and one of the standard cross sections of belt (HJ, HK, HL, HM) used.

The two types described lack convenience in making the changes, and are not "infinitely variable." For such reasons, the trend is toward split pulleys with the faces adjustable by external means and without stopping the machine. Today "variable-speed V-belt drive" generally means one of several types that permit small increments of speed range through a wide range without stopping the operation.

The V-Belt Technical Committee of the Rubber Manufacturers Association has worked during the past year with a representative group of farm equipment engineers in recommending standards for farm machine V-belt drive design, which would be acceptable to both V-belt manufacturers and to farm equipment designers. The final draft of these recommendations is being submitted to the American Society of Agricultural Engineers in the near future.

The following data, which pertains to variable-speed drives, is based on the proposed standard:

Section designation	Nominal width, in	Nominal thickness, in	Max. change of pitch diam., in	Min. OD recommended, in	Speed ratio range with two min. diam.	Total
HJ	1-1/4	19/32	3.732	8-3/4	0.55 to 1.80	3.3
HK	1-1/2	11/16	4.624	10-1/2	0.54 to 1.85	3.4
HL	1-3/4	25/32	5.518	12-1/4	0.53 to 1.89	3.6
HM	2	7/8	6.410	14	0.52 to 1.92	3.7

Diameters larger than the minimum will yield somewhat less in speed range, but will of course permit longer drive service, or will have more power capacity for the same service.

It should be explained that a wide range of groove angles, 22 to 30 deg, has been used by combine manufacturers in past years. Angles less than 26 deg have been used by various makers, and although more difficult, such drives have proven to be workable. To manufacturers of combines which incorporate these drives, the agreement to standardize on 26-deg groove angle represents a compromise with maximum adjustability.

Assuming that 26-deg angle groove design will be used, the groove top width when closed must then be established. In the past, primary consideration has been given to the speed-change factor in selecting the groove top width. When a wider belt is used, the height of the angular face of the sheave is increased, thereby allowing greater belt diameter change. For this reason, you will find that some of the widest V belts are used on the smallest combines. In general, groove top widths have been designed between 1½ and 1¾ in, with a few a little narrower. Also generally speaking, V belts in the range 1½ to 1¾ in width have done an adequate job in handling the power requirements of both cylinder and traction drives.

After deciding upon the most suitable groove top width, the method of accomplishing the desired speed range must be considered.

A single variable-pitch sheave may be used in combination with a fixed-diameter sheave, and the speed adjustment made effective by (a) using thrust spring on the sheave and moving the centers, (b) a thrust spring on the sheave and a movable idler, (c) a mechanical linkage to move the sheave face, and a spring-loaded idler. With the use of a thrust spring, the axial thrust and belt tensions are related as follows on a first approximation basis:

$$\text{Thrust} = \frac{0.00436\,(TA + TB)\,a}{\tan \theta/2}$$

when a = degrees arc of contact
θ = degrees of groove angle
TA = belt tight side tension
TB = belt slack side tension

With the standard groove of 26 deg and with contact arc of 180 deg, thrust = 3.4 $(TA + TB)$. Therefore, when a spring-loaded sheave is being driven from a constant-speed fixed-diameter pulley, a constant-rate spring is the correct type. If, however, the spring pulley is doing the driving, the belt speed decreases as the pulley is adjusted to smaller diameters. Then higher tensions are needed at the slow speeds to develop full power, and to obtain them it is better to use a variable-rate spring, giving more thrust at the smaller diameters.

With both sheaves adjustable in pitch diameter, the speed range ratio of the combination is the product of the values of the two sheaves independently. By moving one flange of each sheave with a lever system, the required length of the belt is not altered, and the full scale of the speed-ratio adjustment can be utilized as indicated in Fig. 1. Still referring to Fig. 1, if A_1 and B_2 are fixed axially, and A_2 and B_1 are moved simultaneously, the belt and sheaves may be kept in perfect alignment at all speed positions. Note that the belt center line shifts position.

With but one sheave adjustable this perfect alignment can be attained at only one speed ratio. This condition becomes more serious as the centers become shorter. To minimize this misalignment, the sheaves should be in correct alignment at the midspeed position.

The two-sheave adjustment range may also be obtained by using two belts driving to and from a floating-center sheave

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 1949, as a contribution of the Power and Machinery Division.

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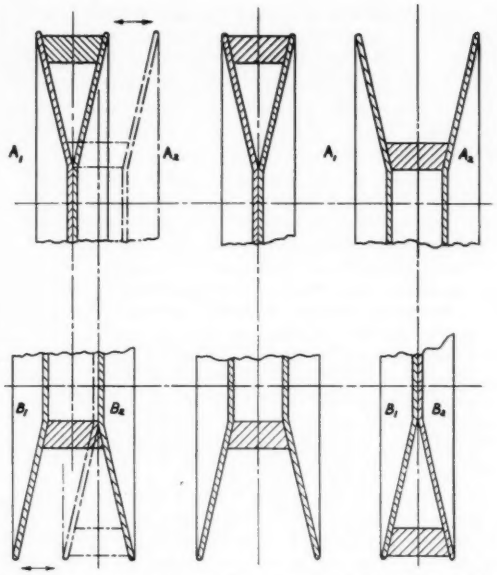

Fig. 1 This drawing indicates how to utilize the full-scale speed-ratio adjustment of a two-sheave variable-speed V-belt drive

as in Fig. 2, the other two sheaves having fixed diameters. By movement of the center disk of the adjustable sheave, the speed adjustment is accomplished. In this design, the adjustable sheave must be movable along a path which keeps the sum of the two center distances constant in order to maintain belt tensions. As the pulley is moved, the belt and the floating center disk seek new equilibrium positions. Note that in the thrust formula, the thrust is independent of diameter.

Therefore, the thrust always tries to reach a balance in such a sheave, and the total tension is the same in each of the two belts. The center disk does not need to be keyed, as a study of the torque paths will show. Friction restricting the lateral movement of the disk must be avoided. The thrust from the two belts acting on different arcs of the disk causes a twisting moment with bearing pressures concentrated at A and B in Fig. 2. A long bearing is desirable and some degree of lubrication must be maintained. The center disk may creep around the sleeve somewhat, helping to keep the disk free. The alignment problem on drives of this type is similar to that of drives which have a single adjustable sheave.

When any type of adjustable pulley is on the driven end of a belt drive, the designer should check the maximum rim

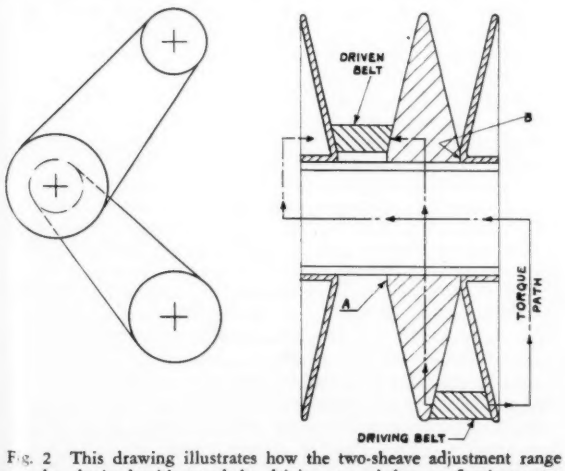

Fig. 2 This drawing illustrates how the two-sheave adjustment range may be obtained with two belts driving to and from a floating-center sheave

speed to make sure it is within safe limits for the material used. For example, a belt running at 5000 fpm lineal speed drives a 2:1 variable speed pulley. When this pulley is adjusted to minimum diameter, the rim is running at 10,000 fpm which is above the safe rim speed for some materials.

We will not attempt to cover the limits of load that may be carried. The conditions of design, use, and expectancy are so varied as to make specific limits meaningless. The present practice in this regard is to use limits in relation to other drives under conditions as nearly like the desired ones as possible. Calculations of the types indicated in this paper will make the comparisons more readily available.

Agricultural V-belt drives, particularly the adjustable-speed drives, are characterized generally by relatively small diameters and extreme overloads.

A comparison with industrial multiple V-belt ratings is of interest. A 1½ in wide industrial belt is rated at 21 hp at 3000 fpm on 20-in pitch diameter pulleys. By service factors for severe industrial use or for long service expectancy, this power per belt is often reduced by one-third or more, or in this case to 14 hp or less. A 1½-in agricultural adjustable-speed belt (HK) may be expected to carry over 40 hp at times at this speed over an effective diameter of 8 in. The smallest diameter for which the industrial horsepower formula will permit any power at all with 1½-in belts is 13 in.

Both diameter and tension affect serviceability of belts by high power relationships. A little increase or decrease causes a large change in the length of service. With diameters small and tensions necessarily high, the need for adequate tension control is to be recognized. Leaving tension adjustment to the chance that the user will get it right is often the reason for short service. Furthermore, with manual control of tension and greatly varying loads, there is a tendency to tighten up the belts when slip occurs at the heavy loads, but no inclination to reduce the tension when the need is past. Then the belt is operating at unnecessarily high tensions for the normal loads.

If normal load tensions are maintained, then the user may allow the belt to slip at high loads. For protective reasons for the other parts of the machine, this can be considered an advantage, but as far as the belt itself is concerned, excessive and continued slipping may be disastrous. In lesser degree, this problem exists in all belt drives where the tension adjustment is a manual operation. In cylinder and traction drives the problem can become acute due to high load and small pulley combinations.

Fortunately there is a rather simple solution in the application of a spring-controlled idler on the slack side of the belt. This permits a total tension in the belt very closely proportioned to the requirements.

The calculation of variable-speed V-belt drives follows the usual belt analysis methods. From the horsepower and the belt speed in 1000 fpm, the effective tension is obtained as follows:

$$\text{Effective tension, } TE = \frac{\text{HP} \times 33}{S}$$

$$\text{Tight-side tension*, } TA = \left(\frac{R}{R-1}\right) TE$$

$$\text{Slack-side tension*, } TB = \frac{TE}{(R-1)}$$

Bearing load (neglecting vector effect) =

$$TA + TB = \left(\frac{R+1}{R-1}\right) TE$$

$$\text{Tension relation, } R = \frac{TA}{TB} = e^{vf\alpha}$$

where $e = 2.718$

v = wedging effect = 4.5 for 26-deg grooves, 3.0 for 38-deg grooves, and 1.0 for flat belts.

f = 0.35 for dry clean surface conditions, but it is usually best to use 0.22 for practical conditions

α = arc of contact in radians.

* Exclusive of centrifugal tension in belt.

Designing to an R of 8.00 is normally about as high as practical. Otherwise, the slack-side tension may become so low that the drive becomes unstable.

Therefore, an R of 8.00 can be used for all values of arc from 120 deg up when the groove angle is 26 deg, except for extremely wet conditions.

$$\text{Then } TA = \frac{38\ \text{HP}}{S},\ TB = \frac{5\ \text{HP}}{S},$$

$$\text{and } TA + TB = \frac{43\ \text{HP}}{S}$$

These formulas are useful in figuring bearing loads and idler mechanisms.

Centrifugal tension is an internal tension having no effect on bearing or idler loads, face pressures or thrust forces. However, as it exists in all portions of a moving belt, its effect must be considered when we wish to know actual tensions in the belt itself.

Centrifugal tension $Tc = 8.63wS^2$, where w = weight of belt in pounds per foot long and S = the speed in 1000 fpm. That this force is not negligible at high speeds is shown by an example. A belt weighing 0.5 lb per ft will have $Tc = 104$ lb at 5,000 fpm.

Now we come to the V belt which is used on variable-speed drives. A problem is faced in the design of variable-speed V belts which does not exist in any other type of V-belt drive. When variable diameter sheaves are used, the minimum diameters at which the belt operates are very small. If the V belts were of a thickness which would be in the usual relation to the top width, they would flex very poorly. In addition, any extra thickness would detract from the up-and-down movement in the variable-diameter sheaves, which would automatically reduce the available speed ratio. Therefore, variable-speed V belts are necessarily wide and thin. To combat the extreme severity of this type of drive, V-belt designers throughout the whole industry have spent endless hours in developing improved product designs. We believe that it will be agreed that great improvements have been made by the belt industry in the variable speed V belt in the past few years.

Part of this improvement was necessary in order to successfully belt the traction drives which have recently come into the picture. New tension members have been found which have added considerably to belt strength and flex life. New rubber compounds have also been developed for this type of belt to withstand the high temperatures which are generated within the belt under high stress and flexing.

We have had the privilege, in past seasons, of observing the operation of self-propelled combines in the rice fields of Arkansas and Louisiana. If ever there was a proving ground, or torture rack, for combines, this is it. The manner in which a combine wades through mud and water, and various mixtures of both, and still digests the huge amount of half-dried straw from a down rice field, certainly reflects a great amount of credit on the men who design the machinery. The farmer may cuss the combine up and down when talking with a factory engineer, but just try to take the combine away from him!

We have endeavored, in this paper, to present most of the design information and other pertinent facts which may be of value to the combine engineer who has use for a variable-speed V-belt drive.

Discussion by L. J. Confer

THE authors E. G. Kimmich and W. Q. Roesler, have indicated the considerable improvement in the quality of variable-speed V belts which has been made in the past few years by the belt industry through intensive development. Surely they will agree that further research and development efforts have not stopped at this point, and it is therefore appropriate to suggest how future developments can possibly be accelerated by adherence to the standards which are to be sponsored by the American Society of Agricultural Engineers.

L. J. Confer, belt engineering dept., The Dayton Rubber Co., Dayton, Ohio.

The design of all types of V belts, the conventional V type as well as the adjustable-speed type, poses many problems in the selection of the optimum points of compromise between opposing requirements.

The selection of the groove angle for the sheaves is the first decision which is made in the design, and it has an important bearing in determining the structure of the belt. We choose between a steep angle such as 22 deg and a flatter angle such as 38 deg or even greater for the sheaves. The steep angle has the advantage of providing greater traction with the same belt tension and the disadvantage of supplying less support for the belt in resisting the tendency to sag in the central part of its trapezoidal cross section. The steep angle also is at some disadvantage in releasing the belt as it leaves the sheave. On the other hand, for variable-speed drives, the steep angle provides greater speed range. We compromise between these conflicting considerations in selecting the sheave groove angle.

The sheave groove angle does not always automatically determine the belt angle. This is particularly true for variable-speed drives. Past experience indicates the approximate differential between the sheave and belt angles, but the optimum belt angle for severe and specialized drives may ultimately require empirical determination, and will be affected by many factors including the width of the belt and the operational diameters.

The heat generated between the belt and the sheaves affects the amount of service which the belt can provide. In turn, the circumferential flexibility of the belt and its crosswise rigidity are factors affecting belt temperature. They are not strictly compatible. In achieving a certain degree of circumferential flexibility, some cross-sectional rigidity is necessarily sacrificed. The optimum point of compromise varies with the top width, the operational diameters and the sheave and belt angle.

For the load-carrying member of the belt we select either that having the combination of maximum tensile strength and shock-absorbing properties, or that having lesser strength but much lower permanent stretch properties, or that having properties between these extremes. Again the sheave dimensions are considered in the choice which is made.

The problem of developing an adjustable-speed belt to maximum quality for a given application is by no means limited to the testing of new rubber compounds, new cords, new fabrics, etc. Much development, or testing, is required to search out the best combination of dimensions and known materials. The dimensions of the sheaves, interrelated with many other factors of the drive, have a bearing either directly or indirectly on almost all elements in the final structure of the belt.

Without detracting from the progress which has been made thus far, we can anticipate that future progress will be at a faster rate if new designs for variable-speed V-belt drives are confined to the one sheave angle, and to the four groove widths which are suggested in the proposed standards and if new designs do not require diameters which are less than the minima recommended therein. Unfortunately the separate developments of belts for each existing variable-speed drive have not had the interrelationship that could be possible. The development of a variable-speed belt for a 22-deg sheave and the development of one for a 30-deg sheave are sufficiently separate problems to invalidate the direct cross application of many of their respective results.

Standardization will make for more rapid development by eliminating some of the variables and thus permit greater concentration on new materials without so much of the time and effort being required to determine the best combination of known materials.

Discussion by W. S. Worley

MR. KIMMICH and Mr. Roesler have presented a very interesting and informative paper on a subject which has almost unlimited ramifications. I should like to comment on certain of the subjects which have been presented, and to add something which may prove helpful to the engineer who is designing a variable-speed V-belt drive.

As the authors point out, one of the major problems in designing a variable-speed drive is to achieve the required speed variation. This is the ratio between maximum and minimum driven speed. For a given belt top width and groove angle, the speed variation which can be realized will vary inversely as the diameter of the sheave—the smaller the diameter, the greater the possible speed variation. On the other hand, as the authors also point out, the service which the belt will render under a given load condition decreases very rapidly as the diameter is decreased.

In order to balance these conflicting needs — small diameters for large speed variations as compared to large diameters for long belt service—it is essential that the variable-speed drive designer establish sheave diameters no smaller than necessary to achieve the required speed variation. This problem is further complicated by the belt length required for different geometrical locations of the belt on the sheaves, and, often, by the requirement that suitable belt take-up may be accomplished without requiring any center distance movement.

Without presuming to go deeply into the subject, I will illustrate a few of the design problems just discussed.

Fig. 1 gives some pertinent diameter-belt length relationships for what we consider to be the ideal type of two-wheel

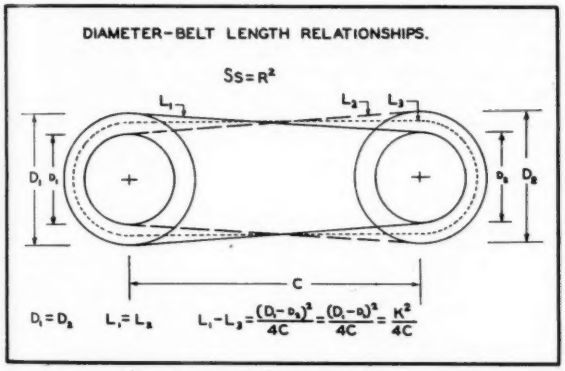

FIG. 1

variable-speed drive. Such a drive is characterized by the fact that the driver speed (R) is a mean proportion between the maximum driven speed (S) and the minimum driven speed (s). This leads to the relationship shown in the figure: $S_S = R^2$.

When this relationship is satisfied, it can be shown that the outside diameter of the driver (D_1) is equal to the outside diameter of the driven (D_2). As indicated on the figure, the belt length required by the geometry of the drive is the same for either of the extreme positions. If, however, we assume the sheaves to have a rigid mechanical link so that the axial opening of one sheave has been equal to the axial closing of the other, the required belt length (L_3) at midposition is shorter than the belt length required at either of the extreme positions. As indicated in the figure, this difference in length is equal to the square of the difference between minimum and maximum pitch diameters (which we call the diameter increment, K) divided by four times the center distance.

To illustrate the significance of this difference, consider an HL cross section adjustable-speed belt, which has a diameter increment of about 5.5 in, running on 12¼-in maximum diameter sheaves, on 16-in centers. The belt length (L_1 or L_2) at extreme position would be 62.32 in. The difference in length between L_1 and L_3 is $(5.5)^2/4\,(16)$, about 15/32 or 0.47 in. The 0.47 in decrease in length, then, represents 0.75 per cent, or about the difference in length between a belt at full tension and one at no tension. On such a drive, if the sheaves were rigidly linked together, a belt could be under satisfactory driving tension at either of the extreme positions; and yet at the midspeed position it might be loose enough that it would not carry the normal power required of it.

This problem becomes even more acute when the drive is one of the type illustrated in Fig. 2. In this situation Ss does not equal R^2. The sheave diameters are not equal, and, incidentally, it can be shown that for the same over-all speed variation the smaller sheave will always be smaller in diameter than that required for a drive using equal diameter sheaves. As for length, the required belt length is not the same even for the two extreme positions. In Fig. 2 the subscript 1 refers to the driver sheave, the subscript 2 to the driven sheave. The equations in the figure show that the driven sheave will be larger than the driver if the product of the extreme driven speeds is less than the square of the driver speed; or, if the product of the extreme speeds is greater than the square of the driver speed, that the driver sheave will be the larger. The third equation states that the difference in required belt length at the two extreme positions is, in absolute value equal to the product of the difference in sheave outside diameters and the diameter increment, divided by the center distance. If, for example, the difference in diameters were 2 in, and as before we were using an HL cross section belt with a diameter increment of 5½ in, and 16-in centers, then the difference in belt length required at the extreme speeds would be 11/16 in.

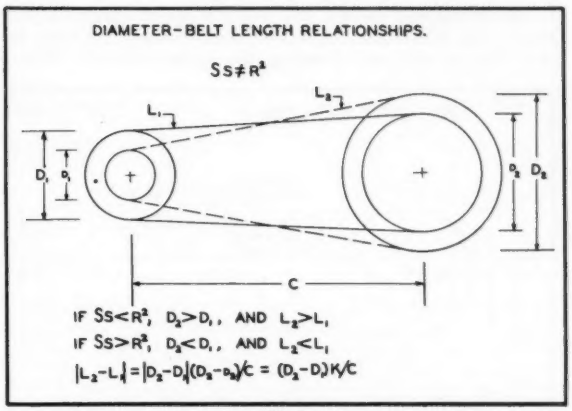
DIAMETER-BELT LENGTH RELATIONSHIPS.
$Ss \neq R^2$
L_1
L_2
D_1 d_1
d_2 D_2
C
IF $Ss < R^2$, $D_2 > D_1$, AND $L_2 > L_1$
IF $Ss > R^2$, $D_2 < D_1$, AND $L_2 < L_1$
$|L_2 - L_1| = |D_2 - D_1|(D_2 - d_2)/C = (D_2 - D_1)K/C$

FIG. 2

The designer of a drive of this type, then, is faced with a dilemma: Although the diameter ratios may calculate to give him the speed variation required, he simply cannot achieve that variation unless the centers are moved as the effective pitch diameter of the belt on the sheaves is changed, or he uses an idler arranged to take up the extra length. The use of an idler, however, is generally precluded by the short center distances on which such drives operate, particularly the cylinder or traction type. Similarly, it is generally impractical to change center distance while speed variation is taking place; as a matter of fact, our experience with variable-speed drives has been that the designer is reluctant or unable to arrange for the center distance to change even for belt take-up. This still leaves the designer with this problem. If he puts on the shorter belt (L_1 in the figure), it will not be long enough for the other position, and will ride at diameters d_1 and some diameter less than D_2. If on the other hand, he puts on the long belt (L_2), it would be too long for the other extreme and would ride at diameters D_1 and some diameter larger than d_2.

Although we cannot go into details here, we can outline the method used by the Gates Rubber Company to get around this dilemma. Essentially we determine by what per cent one

W. S. WORLEY, development engineer, Gates Rubber Co., Denver, Colo.

speed or the other, depending on the problem, will not be attained. Having determined this, we then correct the proper speed and design a drive which theoretically will give us a lower speed or higher high speed by the per cent indicated by our previous calculations.

If, for example, it is desired to have the low speed equal to 300 rpm and our checks indicate that the shorter belt would only achieve 330 rpm, then we have missed the low speed by 10 per cent. We then redesign the drive to give a low speed of 272 rpm instead of 300 rpm. When this has been done, we would not be able to achieve the 272 rpm, but would instead get 110 per cent of that, or 299 rpm, which, after all, is what the problem requires.

As mentioned before, the variable-speed drive designer often finds it necessary to require that provision be made for belt take-up without changing the center distance. Fig. 3

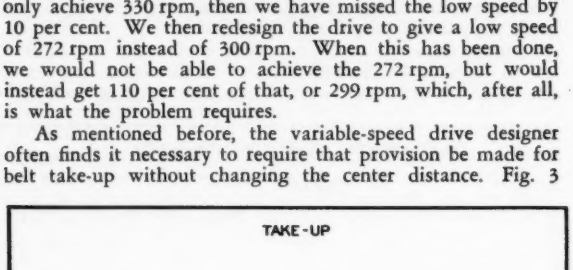

FIG. 3

illustrates a way in which this may be accomplished. As indicated, the drive is so arranged that the shortest new belt will ride at a diameter $D_1 - 2X$ on one wheel and at a diameter d_2 on the other. In this position, the speed ratio, $(D_1 - 2X)/d_2$, is the correct one to achieve the high speed required. Then, as the belt stretches, it can gradually ride out on the large wheel until it runs at a diameter D_1 on the large wheel, d_2 at the other wheel. As the belt continues to grow in length (or take a permanent compression set, which will give the same effect as if the belt had grown), it can then move out to the diameter $d_2 + (2X/R)$. The speed variation at this position is again the same as it was for the shortest new belt. The variation for any belt length in between, however, will be greater than that for either the shortest new belt or the longest old belt.

Achieving belt take-up on the sheaves can be accomplished only by using smaller diameters than would otherwise be required to get the speed variation desired, or, conversely, by accepting less speed variation than would ordinarily be possible with the given set of diameters. The reduction in sheave diameters required to give a specified speed variation and take-up, as compared to those required for speed variation alone, may be rather substantial. We always encourage the designer to exhaust every possibility for getting take-up by center distance variation before deciding that take-up will have to be made on the variable-pitch sheaves.

There are two problems which the sheave linkage must solve: (a) to vary the rate of disk movement to maintain proper belt tension, and (b) to provide means so that the operator can always set the output speed of the drive at any level within the total speed range which he desires. In addition, if centers cannot be moved for take-up, the control linkage should provide some way for adjusting the relative axial positions of the disks to compensate for changes in length or width of the belt. It might be well to consider briefly the two most usual methods of achieving such control.

The authors have mentioned one method: By a mechanical linkage, move the disk of one of the variable-pitch sheaves; and provide for the other sheave a spring which will allow it to exert axial thrust on the belt, so that the belt will ride at the maximum possible diameter consistent with the diameter of the mechanically adjusted sheave and the spring force available for keeping the belt under tension. When such a scheme is used, the spring must change in length by an amount equal to the movement of the disk, which is the bottom width of the belt. This width will vary from 1 in for an HJ section belt to 1⅜ in for an HM section belt. In making such a change in length, the axial thrust exerted by the spring will obviously not be constant. Indeed, if the spring is located on the driven sheave, as it usually is, the spring force will decrease as the driven diameter increases, and the belt slows down. Then as the driven diameter decreases and the belt speeds up, the spring force will increase. This situation should be reversed if the drive is to transmit constant power. For this reason it is generally necessary to choose a very soft, long free-length spring for such an application. The spring is installed under sufficient compression that the force exerted in the slow-speed position is adequate, while there is only a minimum increase in spring force when the drive is operating at high speed.

Fig. 4 illustrates diagrammatically a second type of control linkage which has some advantage over that which has just been described. As indicated, the linkage is almost a solid mechanical one but there is a spring interposed at some convenient point. In this manner the spring in normal operation is required to make only that movement necessary to compensate for the length geometry. This differential movement is usually very small, so that a small diameter, short, stiff spring may be satisfactorily incorporated in the design. At best, however, the simple spring linkage indicated in Fig. 4 is sufficient only to maintain constant tension in the drive at the extreme positions; yet we have already mentioned that the belt tension should vary inversely as the belt speed. Modifications of the linkage shown in Fig. 4 have been made by several manufacturers to achieve the correct relationship between the tension in the belt and the belt speed. If a linkage as diagrammed in Fig. 4 is used where belt take-up on the sheaves is required,

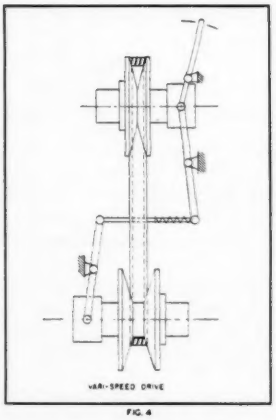

FIG. 4

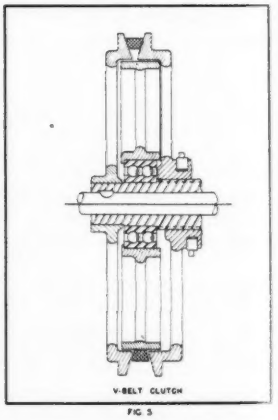

FIG. 5

the installed length of the spring can generally be adjusted periodically by a turnbuckle or other similar device as the belt elongates.

It is sometimes desirable to incorporate into the variable-speed traction drive a device whereby the drive can be completely disengaged from the engine, eliminating the need for a separate clutch. Fig. 5 illustrates the basic principle of a V-belt clutch, although, as shown, it is not applied to a variable-speed drive. The drawing is made from shop prints of a V-belt clutch which has been in continuous service at The Gates Rubber Company since 1932. The upper half of the drawing shows the sheave disks in driving position; the lower half shows the disks opened and the belt riding on a flat idler located inside the driving disks.

The authors in their paper point out the importance of adequate but not excessive belt tension. With this point we heartily agree. Since the use of an axial spring of some sort

to provide belt tension is not only convenient, but almost necessary for variable-speed drives, it is important that the spring force be determined by an accurate formula from the most accurate data or estimate of the power which will be transmitted.

The formula presented by the authors can be derived by a method equivalent to that of determining the hoop stresses in a hydraulically loaded right circular cylinder. In some of our early work on variable speed drives we used this "hoop tension" spring-pressure formula for a certain drive and recommended a force of 1200 lb. When subsequent experiments by the customer's design engineers showed about 400 lb to be all that was necessary for completely satisfactory operation, we decided that further investigation of the problem was required.

Fig. 6 shows a free-body diagram of the forces on a belt in a spring-loaded driven sheave. The principal forces involved are the tensions T and $T + \Delta T$, and the sheave reactions OF. As indicated on the drawing, OP is the normal component of the total reaction of OF, and FP is the total frictional reaction along the side of the sheave. As also indicated, the frictional reaction may be resolved into two components: One (RP) is termed the radial component of friction because it lies in the plane R, which is a radial plane of the sheave. The other (TP) is the tangential component of the frictional reaction, and it is this component which is effective in producing the change in tension as the belt travels around the sheave.

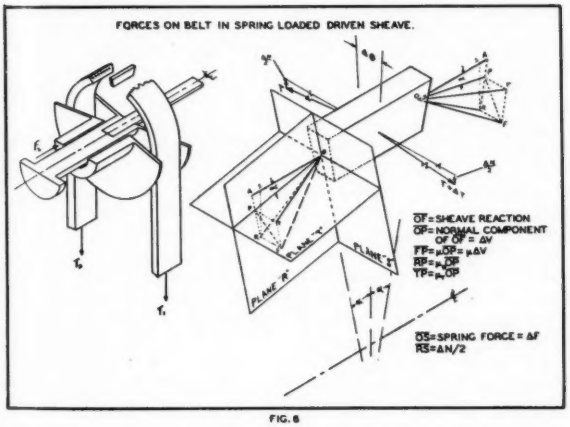

FIG. 6

Without going into detail, it is sufficient to say that an analysis of this situation leads to the following spring-pressure formulas:

Driven: $$F_s = \frac{T_1 - T_2}{2k}\left(\frac{1 - \mu_R \tan \alpha}{\mu_R + \tan \alpha}\right)$$

Driver: $$F_s = \frac{T_1 - T_2}{2k \tan 2\alpha}$$

Definitions:

$$k = \left(ln \frac{T_1}{T_2}\right)/\theta$$

$$\mu = \sqrt{\mu_R^2 + \mu_T^2}$$

$$\mu_T = k(\sin \alpha + \mu_R \cos \alpha)$$

If we assume $\mu = 0.4$, $k = 0.51$, so that, $\theta = \pi$, $(T_1/T_2) = 5$, and $2\alpha = 30$ deg, the formulas given above can be reduced to:

Driven: $F_s = 53.6$ HP/S

Driver: $F_s = 55.6$ HP/S

HP = horsepower

S = belt speed, thousands of feet per minute

When the hoop tension formula is expressed in similar fashion, it gives $F_s = 146$ HP/S, and no distinction can be made between spring force required for a driver and that required for a driven sheave. Note two points of difference between the Gates and the hoop tension formula: A prediction of about 2¾ as much spring force with the hoop tension formula as for the Gates formula; and the hoop tension formula cannot predict any difference in the spring force required for a driver or a driven sheave. These seemed sufficiently important differences that a test program was set up to determine which of the formulas gave better interpretation of the actual requirements.

	SPRING LOAD					
	On Driven				On Driver	Total
Number of Observations	9	8	25	18	6	66
Sheave Angle	30°	22°	22°	22°	22°	
Arc of Contact	180°	180°	180°	178°	180°	
$(T_1 + T_2)$ Measured	306	306	183.5	183.5	306	
$(T_1 - T_2)$ Range, Measured	157 184	45 202	17.9 172	101 118	142 180	
Measured Spring Force Range	299 357	396 432	172 231	202 261	482 516	
Computed Spring Force Range Formula 1	326 360	371 380	210 245	220 221	519 552	
Measured Spring Force Average	319	410	190	227	494	
Computed Spring Force Average Formula 1	331	373	223	221	526	
Computed Spring Force Formula 2	895	1238	742	734	1238	
Ratio: Average Computed, Formula 1 / Average Measured, Formula 1	1.04	0.91	1.18	0.97	1.06	Average 1.03
Ratio: Computed, Formula 2 / Average Measured, Formula 2	2.90	3.00	3.91	3.24	2.51	3.11
Formula 1, (Gates): $F_S = \frac{(T_1 - T_2)}{2k}\left(\frac{1 - \mu_R \tan \alpha}{\mu_R + \tan \alpha}\right)$						$F_S = \frac{(T_1 - T_2)}{2k \tan 2\alpha}$
Formula 2, (Hoop Tension): $F_S = \frac{(0.008720)(T_1 + T_2)}{2 \tan \alpha}$						

TABLE I.

Table 1 is a summary of 66 observations made on the equipment illustrated in Fig. 7. These tests covered variations in sheave angle, total tension and difference in tension (corresponding to differences in horsepower transmitted and also to different tension ratios).

Some tests were made with the spring-loaded sheave acting as driven; others as driver. The table shows the spring force computed from both the Gates formula and from the hoop tension formula, assuming in each case a coefficient of friction of 0.4. The agreement between observed results and that computed on the basis of the Gates formula is good, while the agreement between observed and computed results based on the hoop tension formula is poor, the hoop tension formula predicting from 2½ to almost 4 times the spring force actually required. We feel for this reason that the Gates spring-pressure formula should be used in preference to the formula advanced by the authors.

We must also disagree somewhat with the authors' conclusion that variable-speed V-belt drives on farm machines are "characterized generally by relatively small diameters and extreme overloads". It is true, as they point out, that when compared with industrial applications V-belt drives on farm machines often carry relatively high loads over small diameter

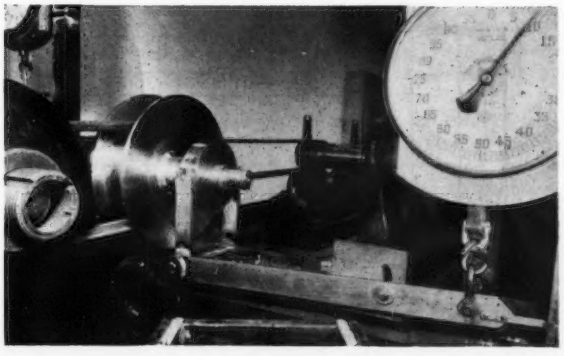

FIG. 7

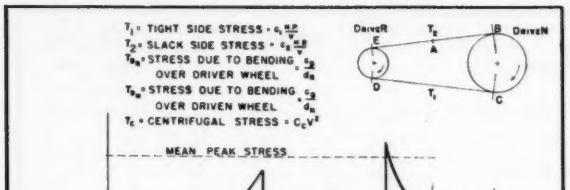
T_1 = TIGHT SIDE STRESS = $c_1 \frac{n^2}{v}$
T_2 = SLACK SIDE STRESS = $c_1 \frac{n^2}{v}$
T_{b_a} = STRESS DUE TO BENDING OVER DRIVER WHEEL = $c_2 \frac{1}{d_a}$
T_{b_b} = STRESS DUE TO BENDING OVER DRIVEN WHEEL = $c_2 \frac{1}{d_b}$
T_c = CENTRIFUGAL STRESS = $C_c V^2$
DriveR
DriveN
MEAN PEAK STRESS
STRESS IN BELT
LOCATION ON DRIVE

FIG. 8

sheaves. There are, however, two yardsticks which such a comparison overlooks. These are:

1 Does the drive transmit the power required by the application?

2 Does the drive transmit this power for a length of time satisfactory to the operator of the machine?

Against these criteria, we think the agricultural V-belt drive in general, and the variable-speed V-belt drive in particular, measure up well. The comparison which the authors make of horsepower ratings for an HK agricultural adjustable-speed belt and an industrial E cross-section belt must be considered with due allowance made not only for the difference in thickness and construction between them, but also for the fact that the criterion of satisfactory service for industrial applications is radically different from that for agricultural machinery applications.

The problem in analyzing the performance of a variable-speed V-belt drive is essentially the same as that of analyzing any other V-belt drive, except, of course, that such analysis must consider the fact that the diameters over which the belt operates, and the speeds at which it operates, do not remain constant. Essentially this process is one of analyzing the stresses to which the belt is subject as it operates around the wheels of the drive. Fig. 8 shows the way in which centrifugal stress, tight and slack side stress, and stresses due to bending, combine to impose on the belt stress peaks each time that it goes over a wheel. Fig. 9 shows the relationship between peak stress and the number of stress cycles which the belt can endure before fatigue failure occurs. The application of these concepts to the design of variable-speed V-belt drives for farm machinery follows essentially the method outlined in Gates bulletin DH-674, although specific data covering adjustable-speed belts has not as yet been published.

We have tried, in Fig 10, to illustrate the complex relationship between the twelve variables in the design of a variable-speed drive. When problems are as complex as indicated, there is real need for close cooperation between the

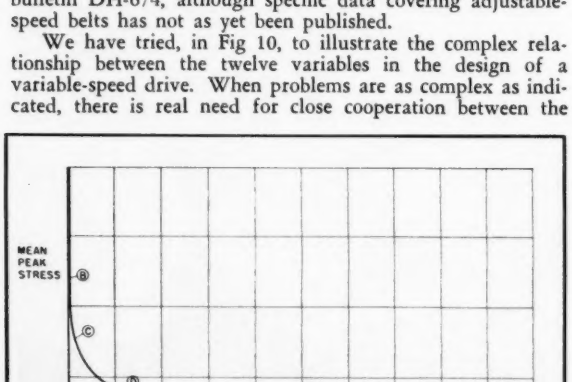

FIG. 9

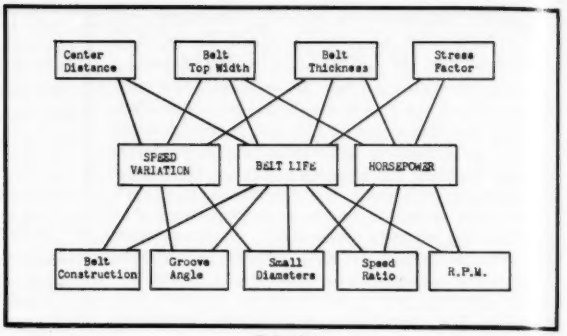

FIG. 10

design engineers of the machinery manufacturer and the belt supplier. Certainly, there must be a clear understanding on the part of both designer and supplier of the variable-speed problem, and the objective which the machine designer has in mind.

There are still many problems which must be solved in the general field of designing variable-speed drives. We have already mentioned the need for satisfactory tensioning to give the right belt tension under all conditions—and most variable-speed drives on farm machines are so close coupled that the spring-loaded idler suggested by the authors is not a practical possibility. There is also need for more consideration to getting take-up by moving the shaft centers rather than by utilizing part of the speed variation which would otherwise be available on the sheave. Certainly there is need for emphasis on designing variable-speed drives so that equal-diameter variable-pitch sheaves can be used. This will present fewer problems in control and tensioning, and will make the most efficient use of a given amount of available space for sheaves.

The versatility of the variable-speed V-belt drive is evidenced by its use on a wide variety of applications. The dependability of a properly designed variable-speed V-belt drive is evidenced by the satisfactory service which such drives have rendered on thousands of combines in all sorts of service.

At the 1947 December meeting of the ASAE, in a symposium on the subject, entitled "Shall It Be Self-Propelled", D. C. Heitshu spoke of the need for a new conception of a prime mover which could be steered from front or back; could either push or pull an implement; would have power not only for propulsion but for the operation of various implements, and would bristle with power take-off shafts extending in practically any direction. He spoke of such a machine as a dream, and for all we know it still is a dream. We would venture, however, to predict that, if that dream does come true, then the unit will be powered with a variable-speed V-belt drive.

Research for Tomorrow's Agriculture

(Continued from page 333)

problems of the agriculture of the future. A lot of atoms remain to be cracked. We have a long way to go in applying the mathematics and analytical mechanics of nuclear fission to these phenomena before we have the last word on the use of atomic energy in agricultural research. Control of the mysterious phenomena of cosmic rays and solar energy must yield sooner or later to the fine analytical mind of some clever young engineer physicist who perhaps will help to produce a food crop rich in nutrients but which will leave the soil enriched in the essential elements of energy and productiveness.

The field of agricultural research is so broad and ever expanding into the dim unknown that there is no safe way of predicting exactly what will be its essential constituents in even the near future. But I believe, from what I have seen even in the relatively recent past, that what we know now is merely a good start and that there will be no dull moments for well-trained agricultural engineers. I admonish you to have faith in the future of scientific agriculture. Remember that the brilliant scientists whom we know almost always have superbly developed imaginations.

Principles of Soil Physics in Relation to Tillage

By G. M. Browning

WE TILL the soil to plant seeds and to help improve air, water and nutrient relationships for plant growth. That sounds simple but it is not. If I asked you, "What are the requirements of a good seedbed?" there would be all kinds of answers. We probably could agree that we want a seedbed that favors high crop yields. But what are the requirements for different crops and climatic conditions? There are many ideas, but actually we do not know. I believe we shall not get the seedbed desired until we really understand the effect of soil structure on plant growth.

How can we expect to build a tillage implement to help develop and maintain good soil structure unless we know exactly what is needed? I am sure I do not know what are the optimum soil conditions for plant growth, but as I visualize it a good seedbed for our major crops has some of these physical and chemical characteristics(3)*: It is one from which the fine grain-like granules or aggregates trickle through your fingers when you pick up a handful of the soil. It feels loose and mellow in your hand but not too loose for good germination of the seed. It is well supplied with readily available organic material. It contains enough large pores to allow rapid moisture movement into it during periods of heavy rainfall. It also allows rapid movement of water into draintiles. It contains enough air so that the millions of soil microorganisms are actively decomposing an abundant supply of readily available organic material, liberating nutrient materials for the plant. The granules and aggregates are in small clumps and not in large clods. The granules are stable and resist the beating action of raindrops. It has these characteristics for the surface 6-in layer that is tilled but in addition it also has favorable air, water and nutrient relationships throughout the entire zone that the roots penetrate.

Maybe we cannot develop and maintain these characteristics in all fields but at least we can work in that direction. Soil structure as we find it today is the result of a combination of factors operating over a period of years in the development and management of the soil. It is more directly affected by the crop and soil management practices since the land has been under cultivation, the type and amount of rainfall, the amount of erosion, freezing and thawing, and tillage practices. Let us consider in more detail some of these factors.

The Soil. The type of soil has a very important effect on the physical and chemical characteristics and on the tillage requirements. A sandy soil has a different air, water and nutrient relationship than a heavy clay soil. A sand has what we call single-grain structure. Sand particles act as independent units and are not grouped together in granules or aggregates. The air supply is usually adequate or excessive but the nutrient and water supplies are often limited. There is usually enough silt in the sand to cause the surface to seal over during hard driving rains. Wind and water erosion is frequently a problem. The other extreme of soil structure is found in the heavy clay soils. The clay particles stick together forming clods instead of true soil granules. The clods are usually dense and have little air within the clod. Clay soils have high water-holding capacity but they usually have low permeability. As a result clay soils are frequently worked too wet. Working soils too wet destroys soil structure and encourages formation of clods. As a result the moisture content is increased and the air supply decreased. Unless large clods are broken down with tillage implements or by freezing and thawing, the seedbed is usually not favorable for optimum plant growth. Fall plowing to allow freezing and thawing during the winter is a common practice to help create mellow clay soils.

The structure of silt loams and loam soils is in between the sands and the clay. The silt loams and loam soils have sand, silt and clay present in amounts that usually are more favorable for developing good structure than sand or clay soils. The silt, clay and organic matter are bound together into granules. A high percentage of large stable soil granules favors air, water and nutrient relationships. Not all silt loam soils have good structure. Soils that are mostly silt with only 10 to 12 per cent clay depend almost entirely on organic matter to bind the particles together into soil granules. The granules may form but usually are not stable in these soils because the granules break down as the organic material decomposes. Soil and crop management practices to supply an abundance of organic material and care to avoid overworking with tillage implements are important on these soils.

Tillage Practices Influence Soil Structure. The moisture content of the soil, the type of soil, and the past management practices influence the time and labor required to prepare a good seedbed. Plowing land too wet destroys soil structure. This is easy to explain. Soil particles when well lubricated with water are easily pushed together during plowing or cultivating. The original granules are destroyed; clods are formed. Structure of this type is not favorable for maximum plant growth. Plowing the land when too dry makes it difficult to prepare a good seedbed. When plowed too dry, soils break up in large clods and unless these clods are mellowed down by alternate wetting and drying or by freezing and thawing, it is difficult if not impossible to prepare a good seedbed. Plowing when too dry is not as destructive to soil structure as plowing when too wet. Working the soil at optimum moistures tends to favor granulation. What is this moisture content? Studies indicate that it is slightly below the field capacity. The field capacity is the moisture content of the soil after it has been saturated and allowed to drain for about a day. It varies for different soils. It is not often that we can hit the optimum soil moisture, but certainly we should not work soil that is too wet or too dry.

Heavy machinery compacts the soil. Just how much our farm machinery compacts different soils with different moisture conditions is not known. If the soil is compacted by machinery or in other ways, the number and size of the large pores are decreased. This leaves air, water and nutrient relationships less favorable for plant growth. Many farmers have asked: "Will plowing at the same depth with tractor and other implement wheels running in the bottom of the furrow develop a plow sole over a period of time?" There is little evidence to indicate that a plow sole has formed under present farming operations, but it is something that needs further investigation. There are several reasons why a definite plow sole has not developed to date. The depth that we plow varies from year to year, plant roots penetrate below the tilled zone, wetting and drying and freezing and thawing in the northern areas — all help prevent an impervious layer forming at plow depth.

Surface Tilth Not Enough. We prepare the seedbed to a depth of from 5 to 7 in with our common tillage implements. Conditions are favorable for plant roots to develop in this zone but that is not deep enough. Roots need to go much deeper than this for an adequate supply of water and nutrients. Extensive areas of soil are known where plant roots are limited to the surface few inches because of an impervious unproductive clay subsoil. The heavy clay subsoil has developed over a period of many thousands of years. We generally have believed that it is not practical to do anything about it. Recent studies in Missouri on heavy clay pan soils show that mechanically loosening the clay subsoil layer and correcting

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* Numbers in parentheses refer to the appended references.

the nutrient deficiencies with commercial fertilizers has increased root development and crop yields(7).

The use of special plows to mix the soil several feet deep suggests another way of improving soils with silty surfaces and heavy clay subsoils. The surfaces of many clay-pan soils are high in silt and low in organic matter and clay. The surface usually has very poor structure. The subsoil is a compacted plastic clay. Mechanically mixing the silty surface layer with clay from the subsoil improves the mechanical composition and should favor aggregate formation. Adding organic matter, as barnyard manure, or through the use of grasses and legumes should further improve soil tilth. Lime and fertilizer when needed to stimulate the development of roots and tops of the crops grown should hasten the process. If this type of soil improvement was shown to be economically feasible, I am sure engineers could find an implement to do the job.

Crop Rotations Influence Soil Structure. Probably the most important single factor affecting soil structure is the cropping system. *Corn, cotton, soybeans, and other intertilled crops destroy soil structure. Grasses and legumes are structure builders.* But what is the proportion of grasses and legumes to intertilled crops to maintain favorable soil structure for different soils and for different climatic conditions? To maintain organic matter and soil structure most soils will require at least as many years of the meadow or pasture crops as intertilled crops in the rotation. Some soils will require twice as many years in meadow as intertilled crops to maintain soil structure. Other soils with application of barnyard manure may be able to stand a higher percentage of intertilled crops than pasture and meadow crops and still have a physical condition favorable for maximum crop production. Studies have been in progress for many years to answer these questions but the work is limited to a few soils. Much additional research is needed to determine the soil and cropmanagement practices necessary to maintain soil fertility, improve soil structure, and control runoff and erosion for different soils and under different climatic conditions.

WHAT CULTIVATION DOES TO SOME SOILS

Let us take a look at what has happened to some of our soils since we started cultivating them. I shall use as an example data from Iowa(1). Comparisons were made of physical characteristics of 6 virgin and adjacent cultivated areas. These soils all developed under prairie vegetation. The cultivated fields have been under the plow for about 60 to 70 years. The virgin areas have been undisturbed. What did we find? On the average the cultivated soils were about 25 per cent heavier, they had lost about one-third of the large soil granules, the granules present were less stable, the organic matter content was about one-third less, and permeability was much lower. If this has happened in the last 60 to 70 yr, where will we be in another 100 years from now if we continue to farm as we have been? I do not know. While we would not expect the total changes to be as large as during the last 50 years, the net effects on crop production may be even greater than in the past. Further deterioration of soil structure and depletion of soil fertility, even though much slower than when the land was first plowed, may rapidly develop unfavorable air, water and nutrient relationship in our soils.

Less favorable physical conditions of the soil as we find them today need further attention in relation to tillage practice and crop production. Soils today are a different tillage problem than when first put under the plow. Too often we have thought it possible to prepare and maintain good soil tilth with tillage implements alone. We have failed to recognize that the use of grasses and legumes regularly in the cropping system is the key to good soil structure and improved soil fertility. The use of tillage implements or soil and crop management alone is not the complete answer. Both practices are important and necessary. Only when the two supplement each other do we build and maintain soil structure with air, water and nutrient relationship favorable for maximum crop yields.

Many investigations have shown the importance of grasses and legumes for the maintenance of soil structure. I will use one example from our studies in Iowa to emphasize this point(5). We measured the number and stability of the large-sized aggregates of the Belinda silt loam on the Albia Pasture Farm in southern Iowa. This soil is a silt loam low in organic matter with poor structure under average farming practices. Here's what we found: After the land had been in grass for 4 years, 26.2 per cent of the soil was in aggregates larger than 1.0 mm. Under a corn-soybean rotation, a cropping system quite common on these soils, there was only 3.7 per cent large stable aggregates. Under a corn-corn-oat-meadow rotation, which is about an average of what farmers are now following, 10.6 per cent of the soil was in these large aggregates. In preparing seedbeds on these areas one could see the difference in soil tilth for different rotations. Actually, though, there was little difference in the amount of time required with the different tillage implements to prepare the seedbed. After the first heavy rain the differences in soil tilth between different rotations were pronounced. The soils were badly sealed at the surface under the rotations that had a limited amount of grasses and legumes and large amounts of clean-tilled crops. The aggregates in areas cropped to grasses resisted the beating action of the raindrops. The soil surface was open and not sealed over. Air and water could readily penetrate the soil and conditions were favorable for plant growth.

Crop Residues in Relation to Soil Structure. The granules in most of the soils in this country are not stable to the beating action of hard driving rains. Crop residues on or near the surface help protect the soil from the beating action of the raindrops. Subsurface tillage implements that leave crop residues on the surface are being very effectively used to control wind and water erosion in the arid wheat section of the West. The implement problems of stubble-mulch farming small grain are much simpler than with clean-tilled, cultivated crops. With row crops, residues on the surface interfere with present planting and cultivating equipment. Crops frequently show greater nutrient deficiency symptoms than on plowed land. The plow apparently leaves the soil with more favorable physical conditions than present subsurface tillage implements. The plow buries the residue and erosion from bare land can be serious. A machine is needed that will prepare a seedbed so that nutrient deficiencies will be minimized, crop production maintained and still provide the protective action of the residues on the soil surface. If we had this machine, then we would still have to sell the farmer on changing from his present machine to this new type of machine. With all the implements we now have the machinery problem should not be too difficult. Revision of existing machines may be all that is required, or development of new machines may be necessary. Until we have the machine and can show that crop yields are not reduced, farmers generally will not accept the practice of leaving crop residues on the surface.

DO STALK CUTTERS MAINTAIN SOIL STRUCTURE?

What About Stalk Cutters? Farmers throughout the corn belt have bought a lot of stalk cutters during the last two years. Do these machines help to solve our residue problem and to maintain soil structure? There is no question but that any practice which will encourage better use of our crop residues is good. Shredding the stalks assures that they go back on the land where they will help protect the soil from wind and water erosion. But this has its own problems. This fall in Iowa I saw wind-blown rows of chopped stalks piled against the field fences following the use of the stalk cutter instead of being on the land where they would do some good. Disking or other methods of tying these stalks down helps but we do not have all the answers to this. Another advantage of cutting or shredding the stalks is that the organic matter is returned to the soil instead of being raked and burned in the spring as too many farmers are still doing. Stalk cutters also eliminate the need for disking or other practices that are commonly used to cut the stalks before plowing. It eliminates the interference of cornstalks in the cultivation of crops, which really is not much of a problem but mostly in farmers' minds. Stalk cutters also kill corn borers. But certainly it is not a

cure-all for the borer problem as some people would like to have us believe. Our entomologists tell us that even though stalk cutters kill 50 per cent or more of the borers, it may have little or no effect on the borer population the following year. Other control methods such as clean plowing have the same limitations since it has been shown that unless virtually all of the borers are killed, the population the following year may still be sufficient to cause serious damage if weather conditions are favorable.

Better methods of handling our soybean residues is another step that we can take to help maintain soil structure. Most of our soybeans are combined without the use of a straw spreader. The straw drops to the ground in large bunches. Plowing through unspread soybean straw certainly is an unpleasant task. It is not surprising, therefore, to find farmers raking and burning soybean residue. This destroys much valuable organic matter. Farmers tell me that straw spreaders on combines do not do the job that is needed in handling the soybean residue. I do not know whether this is a just criticism or not. If it is, certainly the development of spreaders that will do the job, and greater emphasis to encourage farmers to use spreaders, will pay dividends in the long run.

Where are we today in making the most effective use of crop residues to control runoff and erosion and maintain soil fertility? I believe we must admit that for row crops we have not scratched the surface. Here is a place where agronomists, agricultural engineers, and others can team up together and make a real contribution to agriculture.

A Look at Our Present Tillage Implements. The first operation in the preparation of a seedbed is to stir the soil with some implement. Many have been used. Some are adapted to one set of conditions and others work better under other conditions. The plow, the lister, the disk, the subsurface tiller, the rototiller, and various modifications of these implements have and are now being used in the initial preparation of the seedbed. Today the plow is the most widely used implement for primary seedbed preparation on farm lands of this country as well as other countries. On heavy grass sod it is still the most effective and economical implement now available. It turns the soil over and loosens it perhaps more than any other tillage implement now in use. It buries, or partially buries, the organic matter. The soil is left bare. Erosion can be serious on unprotected land unless supplemental erosion control practices are adopted. The plow has been condemned as an erosion hazard. It has made possible rapid exploitation of our soils. However, serious erosion of our farm land is mainly the result of high acreages of soil depleting, erosive intertilled crops and low acreages of soil-conserving meadows and pastures, without supporting mechanical practices such as contouring, strip cropping and terracing to help control erosion. We have been slow in recognizing that our soils are "washing away" and "wearing out". Instead, too many still believe that to plow, plant, cultivate and harvest is all that is necessary.

ADVANTAGES OF LISTER IN SOME SOILS

On some soils the lister is used for planting corn, soybeans and cotton. It has several advantages where it can be used. About one-half as much time, power and labor are required to plant corn with the lister as compared with corn surface-planted on plowed land. Weeds can be controlled easier on listed corn than with plowing and surface planting. With rows on the contour, listing is about twice as effective in conserving soil and water as surface-planted corn. On soils suited to listing, yields from lister planting are as high or higher than yields on plowed land. But with all the advantages of listing, there are limitations to its use. Our studies in Iowa show that stands of corn were 10 per cent lower on listed corn than on corn suface-planted on plowed ground. This is not surprising since with listing the crop is planted at the bottom of the furrow in cool, wet soil without previous seedbed preparation. Changes in the present lister to provide for a better seedbed at the bottom of the furrow should be helpful in improving the stand and overcoming nutrient deficiencies.

On eroded soils the lister plants the seed in the subsoil which is often unproductive. The use of commercial fertilizers may help overcome the nutrient deficiencies frequently found under these conditions, but I do not know of a good fertilizer attachment for a lister planter. Little work has been done to show the amount, kind, method and time of application of fertilizer to crops planted with the lister. Legumes and grasses regularly in the rotation will also help improve the structure of the subsoil. The lister is being used to advantage on many soils throughout the country. Its use probably could be expanded to advantage if studies were available to show on which soil it can be used and the soils on which it is not suited.

The disk harrow is an implement found on most farms throughout the country. It is a very convenient tool and when used properly and at the right time is an effective tool in seedbed preparation. It does not work well in rocks. It prepares the seedbed with a cutting action. Any implement of this type, especially if used excessively, will cut and destroy soil aggregates and unless judiciously used can be quite harmful. The general tendency is for farmers to disk too many times. This often is necessary to prepare what they think is a satisfactory seedbed. At best, the disk prepares a shallow seedbed, cutting not more than 2 or 3 in deep, unless it is a disk tiller or disk plow and unless it is heavily weighted. Most disks are not kept sharp and unless the soil has unusually good tilth too many operations of a disk are required to make it an economical method of seedbed preparation.

The subsurface tiller and field cultivator are implements with sweeps that operate under the surface, loosening the soil without inverting it. The residue of small grain or cornstalks left on the surface protect the soil from runoff and erosion. The subsurface tiller and field cultivator have many desirable features, but compared with seedbed prepared with the plow, plants develop more nutrient deficiency symptoms and crop yields are reduced. A machine that would loosen the soil as the plow does but still leave the crop residues on the surface would have many advantages. If that machine is in existence today I do not know about it. I believe there is a real opportunity along this line, and I hope increased emphasis will be directed toward developing such a machine.

ROTARY TILLERS IN SEEDBED PREPARATION

Recently there has been much interest in rotary tillers. These machines have been used very effectively in seedbed preparation for vegetable production. A number of farmers have tried rototillers under general farm conditions. Reports of their success are conflicting. Some say they work and others say they do not. The power requirements of a rototiller are such that a separate engine is needed. On the average farm such a machine is probably not an economical unit. The greatest drawback to the rototiller is that it stirs the soil more than most other machines and can be expected to break down soil structure more. This may be good on heavy clay soils, but on silt loam soils of poor structure the tendency is for the surface to crust over during the first rain and erosion can be serious if the land is sloping.

There is difference in the efficiency of these machines which in our present-day farming practices is becoming more and more important. Agricultural engineers have figures on the cost of operating different machines. Farmers and agronomists are interested in which of these machines is best adapted to a particular condition to help control erosion and still maintain high crop production.

Tillage Practices Affect Crop Yields. In Iowa we have compared yields of corn with some of these tillage implements during the last 15 or more years. I believe you will be interested in a brief account of this. In western Iowa during the period 1944-48 we compared yields of corn when the seedbed was prepared with the plow, the hard-ground lister and the subsurface tiller(4). We also had these same treatments with no fertilizer and with a complete commercial fertilizer. These studies were on farmers' fields, but they were randomized experiments with four replications of each treatment. On 43 soils representing 5 soil types during 5 years, here is what we found: The per acre yields on the unfertilized areas were,

plowed, 71.4 bu; hard-ground listed, 68.9 bu, and subsurface tilled, 67.4 bu. When commercial fertilizer was added, the yield on the plowed areas was 74.0 bu per acre; hard-ground listed, 74.0, and subsurface tilled, 71.7. These differences are not large and statistically are not significant. These are permeable well-aerated soils and the effect of different tillage practices on yields is not as evident as on other soils with less favorable physical conditions.

We do not have as many years or as many fields on these soils with less favorable physical conditions but we do have some information. In the flat slowly drained and frequently wet Webster silty clay loam near Ames, corn yields per acre on the plowed plots were 59.6 bu; hard-ground listed, 44.4 bu, and subsurface tilled, 51.1 bu. These are the average of one field in each of the years 1944, 1945 and 1946.

Tillage Practices Affect Nutrients Availability. Why is there a larger difference in the yields on these poorly drained soils than on the well-drained soils? It is tied up with the air, water and nutrient relationships. We found that on the listed and subsurface-tilled plots the corn developed marked signs of nitrogen and potash deficiency. In midsummer we took plant samples and determined the nitrogen and potash content(2, 6). We also took soil samples to see the effect of different tillage practices on the exchangeable potash in these soils. Here are some of our results: The weight of plants on the unfertilized plots at this time in grams was, on the plowed, 599, hard-ground listed, 330, subsurface tilled, 461. These are large differences. The nitrogen content of the plant on these same plots was: plowed, 1.80 per cent; hard-ground listed 2.13 per cent; subsurface tilled 1.92 per cent. These differences are small and are not statistically significant. The potassium content on these same treatments was: plowed, 1.61 per cent; hard-ground listed, 1.04 per cent and subsurface tilled, 0.98 per cent. The low potassium content of the plants for hard-ground listed and subsurface tilled is important. The listed and subsurface tilled plots showed marked symptoms of potash deficiency. We found no difference in exchangeable potassium, the form available for plant growth, under the different tillage practices. Studies have shown that potassium utilization by plants is related to the soil aeration. The soil under different tillage treatments had the same amount of exchangeable potassium but plants can not utilize it unless there is an adequate supply of oxygen present. Measurements show that the soil is more compact and not as well aerated on the subsurface-tilled and listed plots as on the plowed plots. The stand on the subsurface-tilled plots was the same as on the plowed plots but the plants were smaller, stalks were smaller, and the yields were less. It appears, then, under the plowed areas the soil was looser and better aerated than under the listed or subsurface-tilled plots.

INFLUENCE OF MANAGEMENT ON TILLAGE PRACTICES

Past Management Important. We noticed throughout these studies which compared the effect of different tillage practices on corn yields that past management was a very important factor regardless of the soil. If the soil had been well managed with grasses and legumes regularly in the cropping system and barnyard manure had been used, there was little or no difference in the yields of corn regardless of the tillage implement used. The yields were all high. On other fields where soil fertility had declined and soil structure had deteriorated, the plow, which loosens the soil more than the other tillage practices, consistently gave higher yields. The plants showed some nutrient deficiency symptoms on all plots on the slowly drained soils but were much more pronounced on the hard-ground-listed and subsurface-tilled plots.

What this means is this: If we have good soil and crop-management practices, which we are a long way from at the present time, almost any tillage implement is satisfactory. With good soil and crop-management practice we do not have to worry so much about seedbed preparation with tillage implements because we have developed a good physical and chemical relationship in the soil which favors air, water and nutrient relationships for high crop yields. When the soil has been overcropped to structure-destroying intertilled crops, then the tillage practices that loosen the soil most gives the best results. Under these conditions tillage implements can be used to improve temporarily the physical condition of the soil, but it is only a means to an end: It is not the entire answer. We need to combine the effects of good soil and crop management practices to maintain stable soil structure and then to supplement this with tillage implements to further improve the physical condition of the soil for high crop production.

More Research Needed. We have made much progress in solving problems that relate to tillage and soil structure but additional work needs to be done. We have yet to see shifts from soil-depleting row crops to soil-conserving grasses and legumes that are necessary if soil productivity is to be maintained or improved over the long pull. Much progress has been made in developing sprays for certain crops and weeds. Further development along this line may completely revolutionize present tillage practices. The meadow in the rotation not only improves soil structure but is in itself one of our most effective weed-control measures. If enough meadow is included in the rotation to maintain favorable air, water and nutrient relationships, the need to till the soil and cultivate intertilled crops to improve soil tilth and control weeds is largely eliminated. Under these conditions we may even visualize a single machine to prepare the seedbed and plant the crop in a single operation. The crop residues would be on the surface to protect the soil from erosion, the surface would be left rough to impound water providing for optimum use of rainfall, and sprays would control the weeds. The next operation would be harvesting the crop. This would reduce the cost of producing crops and at the same time avoid the destructive effect of tillage practices on soil structure.

I do not believe this is wishful thinking; it is a real possibility. It is a challenge to cooperation between several fields of interests: the agronomists to find the crop rotation and soil management practices to maintain soil fertility and soil structure favorable to maximum crop yields; the entomologist and chemist to develop sprays to control insects and weeds; the engineers and implement manufacturers to design and build spraying and tillage machinery; the animal husbandryman to determine a livestock program to best utilize the crops produced, and last, but not least, the economists to help plan for the greatest returns with the long-time over-all objective, the maintenance of our most valuable natural resource — *the soil.*

REFERENCES

1 Anderson, M. A. and Browning, G. M.: Some Physical and Chemical Properties of Six Virgin and Six Cultivated Iowa Soils. Soil Sci. Soc. Amer. Proc., 14: (at press) (1949).

2 Bower, C. A., Browning, G. M. and Norton, R. A.: Comparative Effects of Plowing and Other Methods of Seedbed Preparation on Nutrient Element Deficiencies in Corn. Soil Sci. Soc. Amer. Proc., 9:142-146 (1944).

3 Browning, G. M.: Research Needs of Tillage in Soil and Water Conservation. Jour. Soil and Water Conservation, 3:75-80 (1948).

4 Browning, G. M. and Norton, R. A.: Tillage Practices With Corn and Soybeans in Iowa. Soil Sci. Soc. Amer. Proc., 12:491-496 (1947).

5 Feng, C. L.: The Effect of Crop Rotations on Soil Aggregation and Related Characteristics in a Belinda Silt Loam Soil. Thesis for doctor of philosophy. Iowa State College (1947).

6 Lawton, Kirkpatrick: The Influence of Soil Aeration on Growth and Absorption of Nutrients by Corn Plants. Soil Sci. Soc. Amer. Proc., 10:263-269 (1946).

7 Smith, D. D., Woodruff, C. M. and Whitt, D. M.: Building a Soil Deeper. AGRICULTURAL ENGINEERING, vol. 28, pp. 347-48 (1947).

An Investigation of Evaporation from Irrigation Sprays

By John R. Mather

ALTHOUGH the economic advantages of irrigation have been discussed by many authors (2, 3, 4,)*, some of its physical aspects have received little attention. The problem of the total evaporation from an irrigation spray and the associated moist field is generally not considered in investigations of the evaporation from free-water surfaces, soils, and plants.

Irrigation experts have long realized that a certain amount of the total water applied by irrigation must be lost by evaporation into the air. The actual amount evaporated and the nature of its diurnal fluctuations are, however, usually no more than guesses. Having no actual data with which to work, one irrigation engineer increased the length of irrigation application at a given place from a moveable sprinkler by one minute for every hour of the day from early morning until about 3 p.m. to compensate for the increasing rate of evaporation. After 3 p.m., the length of application was decreased by one minute for every hour. The lack of definite knowledge about this subject has probably led to other similar "rules of thumb."

In investigating the evaporation from irrigation sprays at Seabrook Farms, Seabrook, N. J., two different types of irrigation systems were available for study. The first was a fixed overhead sprinkler system. Long irrigation lines permanently placed 5 ft above the ground and 50 ft apart were equipped with small nozzles every 4 ft to spray fine streams of water under a pressure of about 40 psi onto the field considered. Water from each nozzle irrigated an area of 200 sq ft at the rate of approximately 0.09 iph.

The second type of irrigation system used in this investigation was a rotating sprinkler connected to a portable surface line and operating under a water pressure of between 90 and 100 psi. This sprinkler, rotating once every 2 min, threw spray in a circle of 150 ft radius. The rate of application was approximately 0.4 iph.

In this paper, data on the change of the dew-point temperature of the air as it passes through the spray from both of these irrigation systems will be presented and used in preliminary calculations of the amount of evaporation occurring.

Dew-Point Temperature Observations. Dew-point temperatures were obtained with the portable dew-point thermometer described in (6) at 7, 3, and 0.5 m elevation in the atmosphere both to windward and leeward of the irrigation sprays. The portable dew-point thermometer is so designed that air can be brought from any desired source through a plastic tube to a small chamber which houses a mirror. A source of heat and cold attached to the mirror permits the observer to produce and control any desired dew film surface on the mirror. In actual operation, a light is directed onto the mirror which is viewed visually through an observation tube. The small oscillation from a dew film to no dew film can be seen and the temperature of the mirror so regulated that a constant, very light dew film is maintained on the mirror. The temperature of the mirror, measured with a sensitive mercury-in-glass thermometer, is the dew-point temperature of the air. The apparatus used for this investigation was portable and weighed less than 10 lb. Without such a portable dew-point thermometer it would not have been feasible to undertake measurements of the moisture content of the air near irrigation sprays for the various psychrometers and other humidity measuring instruments in use today are not accurate enough to give the desired instantaneous measurements at various levels in the lower atmosphere.

In each set of observations, the vertical distribution of dew-point temperature was found first to the windward of the irrigation system in the air uninfluenced by the irrigation spray. Then, to measure the influence of the spray and moist field on the moisture content of the air, the dew-point thermometer was moved directly downwind to some position within the irrigated area. If a large enough area was being irrigated, several different observations were made downwind to investigate the rate of increase of moisture in the air with increased field length.

The actual observation of the dew-point temperatures in the fields equipped with overhead irrigation lines, along with the wind and sky conditions, and the locations of the observation points, will be found in Table 1. The increase in the moisture content of the air downwind is most marked near the surface and occurs principally within 15 or 20 m of the edge of the irrigated area. As the distance downwind increases with more irrigation lines in operation, the increment of moisture added to the air by evaporation from the spray and moist soil becomes less. At an elevation of 7 m, the air is almost homogeneous because the spray from these overhead irrigation lines does not reach an elevation of over 3 to 4 m and the irrigated field is not large. In a larger field, the dew-point temperature at 7 m within the irrigated area might be higher than that outside because some of the moisture would certainly be transported upward by turbulence.

The observations of the dew-point temperatures to windward and leeward of the rotating sprinkler irrigation system, along with the wind and weather conditions and the location of the various observation points, are given in Table 2. The first observations were taken only at very low elevations, but later a 7 m observation was included. Since the spray reached a height of at least 10 to 12 m, the air at 7 m was still affected. However, the observations indicate only a slight increase downwind in moisture at the higher levels and a greater increase in the lower levels where the effect of the moist soil and vegetation cover is greatest.

By means of these actual observations of the increase in moisture content of the air through an irrigation spray, estimations of the amount of evaporation into the air have been made.

Evaporation from Irrigation Spray. J. E. Christiansen (1) developed an expression based on thermodynamic reasoning for the evaporation of water from an irrigation spray. It showed, after the substitution of the results of field tests, that less than one per cent of the water discharged was evaporated from the spray in the air. Christiansen had no way of estimating the evaporation from the moist land but suggested that this loss must far exceed the loss from the spray in the air.

Two somewhat similar methods which give approximate figures for the amount of evaporation will be discussed in this paper. In considering the spray from overhead irrigation lines, we assume that at 7 m the dew-point temperature is essentially the same both upwind and downwind. This would mean that all the moisture added to the air occurs below 7 m. Consider then a volume with the following dimensions: 7 m high, unit width, and a length equal to the horizontal distance between dew-point observation points. The flux of moisture through the vertical section downwind ($\rho u h w W_{down}$) minus the flux of moisture passing through a similar vertical section upwind ($\rho u h w W_{up}$) will give the total increase in moisture of the air in passing through the inclosed space. To obtain the

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* Numbers in parentheses refer to the appended references.

TABLE 1 DEW-POINT TEMPERATURE, WIND, WEATHER, AND EVAPORATION OBSERVATIONS IN FIELDS IRRIGATED BY OVERHEAD IRRIGATION LINES

Date	Aug. 3, '49		Aug. 11, '49		Aug. 12, '49		Aug. 15, '49		Aug. 17, '49			Aug. 19, '49			Aug. 20, '49				Aug. 27, '49		
Irrigation	0.09 iph		0.18 iph		0.18 iph		0.18 iph		0.09 iph			0.09 iph			0.09 iph				0.09 iph		
Wind velocity	5 mph		4 mph		4.5 mph		5 mph		6 mph			6.5 mph			4 mph				5 mph		
Sky	Scattered clouds		Scattered clouds		Light overcast		Light overcast		Scattered clouds			Scattered clouds			Scattered clouds				Clear		
Field in	Beans		Beans		Beans		Beans		Broccoli			Broccoli			Broccoli				Broccoli		
Dew-point obs., C	U*	D* 100m	U	D 18m	U	D 15m	U	D 15m	U	D 52m	D 88m	U	D 40m	D 60m	U	D 40m	D 80m	D 120m	U	D 45m	D 10[illegible]m
7 meters	23.6	23.4	23.4	23.2	22.6	22.6	18.6	18.4	18.2	18.3	18.3	17.0	17.0	16.8	10.1	10.6	10.5	10.3	23.0	23.0	23.0
3 meters	24.1	24.9	22.9	23.7	22.8	23.2	18.8	19.0	18.3	18.7	18.9	17.5	18.0	18.1	10.4	10.6	10.7	10.8	23.3	23.6	23.8
0.5 meters	24.4	25.5	23.6	24.8	23.3	23.8	19.0	19.8	18.5	19.4	19.9	17.8	18.7	18.5	11.3	12.0	11.9	11.9	23.5	24.0	24.6
Evaporation, per cent†	17		32		17		14		17	17		28	21		14	7	4		17	14	
Evaporation increment, per cent ‡									12			3			0	0			9		

* U indicates observation taken upwind outside irrigated area.
D indicates observation downwind. Distance downwind indicated in meters below D.
Within irrigated area.

† Indicates evaporation as percentage of application from U to that observation position.

‡ Indicates evaporation as percentage of application between indicated observation points within irrigated area.

increase in moisture per unit area this difference should be divided by the surface area over which the air travels (lw). If the amount of water applied to the area is known, the evaporation as a percentage of the amount applied may be obtained from the following:

$$E = \rho\, u\, h/l\, (W_{down} - W_{up})\, 1/A$$

where W_{up}, W_{down} = mean mixing ratio upwind (out of irrigated area) and downwind (within irrigated area)
h = vertical distance to homogeneous air, cm
l = distance between upwind and downwind points, centimeters
u = wind velocity, centimeters per second
ρ = density of the air
A = amount of water applied in centimeter depth per second
E = evaporation as percentage of application.

The computed evaporation amounts or the evaporation that occurs in the distance between the observation point outside the irrigated area and each of the observation points within the irrigated area as a percentage of the water applied, are given in Table 1. These values range from about 4 to 30 per cent which seem high, but it must be remembered that this indicates that the actual amount of evaporation is only between 0.004 and 0.05 iph. The evaporation increment figures given in the same table and ranging from 0 to 12 per cent indicate the amount of evaporation occurring between successive observation points within the irrigated area. This evaporation is actually small and approaches zero as the irrigated area increases in size. The necessary assumptions place severe limitations on the accuracy of these results, but they may be taken as indicating at least the order of magnitude of the total evaporation from both the spray and moist soil.

TABLE 2. DEW-POINT TEMPERATURE, WIND, AND WEATHER OBSERVATIONS AROUND ROTATING SPRINKLER SYSTEM

Date	July 29, 1949		July 29, 1949		July 30, 1949		Aug 25, 1949	
Irrigation	0.4 iph		0.4 iph		0.4 iph		0.4 iph	
Wind velocity	5 mph		6 mph		3 mph		3.5 mph	
Sky	Scattered clouds		Scattered clouds		Scattered clouds		Clear	
Field in	Beans		Beans		Beans		Bare	
Dew-point obs., C	U*	D*	U	D	U	D	U	D
7 meters	.....	.....	.....	.....	.....	.....	9.0	10.0
3 meters	.....	.....	.....	.....	.....	.....	9.3	12.2
2 meters	24.9	25.4	23.8	24.6	24.8	25.3	.....	.....
1 meter	25.1	25.8	24.0	24.8	25.3	25.6	.....	.....
0.5 meter	25.2	26.0	24.6	25.3	25.8	26.3	9.8	12.9

* U indicates observation upwind outside irrigated area.
D indicates observation directly downwind on far side of irrigated area.

With the rotating sprinkler irrigation system, it is not possible to compute evaporation from measurements of moisture gain in the air stream. A different method can be used, however. Knowing the vertical and horizontal dimensions of the spray and the wind velocity, the total volume of air passing through the spray per unit time may be computed. If the original moisture content of the air is known, the amount of water necessary to saturate this volume of air may be computed. This will give a maximum value for the amount of evaporation taking place, for it is hardly likely that all the air in the volume will become saturated in passing through the spray. Dividing the total increase in moisture by the horizontal area over which the air travels and the amount of water applied, the evaporation as a percentage of the application will be obtained.

$$E = \rho\, u\, B(W_{sat} - W_o)\, \frac{1}{A\,\pi\, r^2} \qquad [1]$$

where $(W_{sat} - W_o)$ = change in mean mixing ratio between original air and final saturated air
B = cross-sectional area under spray, square centimeters
r = radius of the spray, centimeters.

The final saturated air temperature and hence its mixing ratio is very difficult to obtain both theoretically and experimentally. It may be well approximated, however, from a consideration of thermodynamic principles. The final equilibrium temperature is the result of two processes which occur simultaneously. One is the transfer of heat from the warm air to the cooler water; and the other is the cooling of the air by the evaporation of the water into it. For simplification, let us consider these two processes separately.

For the final equilibrium temperature due to heat transfer between the air and the water, we may write:

$$\rho_w\, c_w\, V_w\, (T_{wo} - \overline{T}) = \rho_a\, c_a\, V_a\, (\overline{T} - T_{ao})$$

where c_a, c_w = specific heat of air and water
V_a, V_w = a specified volume of water and the accompanying volume of air
T_{ao}, T_{wo} = original temperature of the air and water
$\overline{T}$ = final equilibrium temperature.

Let $c_w = 1$, $c_a = 0.24$, $\rho_w = 1$, $\rho_a = 1.2 \times 10^{-3}$. V_w/V_a varies with the size and number of the water droplets, being less than 10^{-5} for drizzle and as much as 10^{-5} for very heavy rain with 2×10^{-5} a possible value for the very heavy spray from the rotating irrigation sprinkler under consideration.

Substituting and solving,

$$\overline{T} = \frac{1}{1.1}(T_{ao} + 0.1\,T_{wo})$$

Hence, the final equilibrium temperature due just to the transfer of heat between the air and water is only slightly below the original air temperature depending on the air-water temperature difference.

The second process, the cooling of the air by evaporation, however, can cause a large change in the air temperature. Evaporation of moisture into the air produces a two-fold effect. First, the heat taken from the air to evaporate the water will cause a lowering of the air temperature, and, second, the addition of moisture to the air causes an increase in its dew-point temperature. As evaporation into the air proceeds, the air temperature and the dew-point temperature approach each other and at saturation the two are the same. No more evaporation into the air is possible. The final equilibrium temperature due to saturation of the air by evaporation into it can be computed from suitable charts knowing just the original air and dew-point temperatures and the approximate air pressure.

The two processes of cooling the air, by heat transfer and by evaporation, will occur simultaneously. The final saturated equilibrium temperature of the air due to both processes is lower than that obtained from either process individually. However, as a first approximation, it approaches the final equilibrium temperature obtained from saturating the air by evaporation of moisture. If we make use of this value in evaporation computations, we will arrive at a value of evaporation slightly in excess of true conditions. Bearing this in mind, we may now run through a hypothetical example to see the order of magnitude of the evaporation taking place.

Example: Let $u = 2mps$, $B = 4\text{x}10^6$ cm, $T_{ao} = 32$C, T (at dew point) = 25C, $W_o = 20.4$ g per kg, final equilibrium $T = 26.8$C, $W_{sat} = 22.6$ g per kg, $A = 0.3\text{x}10^{-3}$ cm. depth per second.

The percentage of evaporation may be computed from equation [1] and is found to equal about 10 per cent of the water applied. Field measurements of $\overline{T}$ and B have not progressed far enough to permit a more refined computation at this time.

A rough calculation of the difference between early morning and midafternoon evaporation may now be made. The above example may be taken as representative of midafternoon conditions. If we take $T_{ao} = 26$C, T(at dew point) = 24C, $W_o = 18.5$ g per kg, final equilibrium $T = 24.5$C, $W_{sat} = 19.1$ g per kg, no change in V, B, or A, for the morning conditions; this will give an E of about 3 per cent. Three per cent of the water applied will evaporate in the morning as compared with 10 per cent in the midafternoon. These figures based on the assumption of complete saturation of the air are possibly double the actual evaporation. They indicate that only a 2 to 3 per cent increase in irrigation time over, say, a 6-hr period is necessary to compensate for the increased evaporation occurring during the day. Actually, if maximum evaporation did not take place, probably a 1 per cent increase would suffice. However, these computations indicate only orders of magnitude and should not be overworked.

One interesting point might be brought up here. If the irrigation water was very cold, the final equilibrium temperature might be below the prevailing dew-point temperature of the air. In this case, instead of evaporation into the air, the cooling of the air by the water droplets would produce condensation. More water might reach the ground than was discharged by the sprinkler if the condensed water was not evaporated again. Actually for condensation to occur, very cold water would have to be sprayed into air the temperature of which was very near its dew point.

Results. The observations of dew-point temperature require little discussion. Since the instrument is set and read visually, it is subject to slight errors depending on the observer. The maximum error in the readings is certainly not over 0.2C and very likely is less than 0.1C. In most of the observations about one hour elapsed between the first set of dew-point readings and the last. As a check, the dew-point readings outside the irrigated area, which were read first, were repeated at the end of the observation period and only those cases with little or no change in the upwind dew-point temperature over the observation period have been presented here. All dew-point temperatures are the averages of either two or three observations at each level.

The computations of evaporation demand more discussion. It will be noted that the percentage of evaporation from the spray of the rotating sprinkler is somewhat less than that from the spray of the overhead irrigation lines. This may be so for although the air may not reach saturation in the latter case, the amount of evaporation that occurs is so large in proportion to the amount of application that on a percentage basis the evaporation figures appear greater. Actually from 0.004 to 0.05 in of water evaporates every hour from the overhead irrigation line spray area while about 0.04 in per hour evaporate from the rotating sprinkler spray area. Hence the total evaporation per hour is nearly the same. But in that hour, four and one-third times more water is applied by the rotating sprinkler system. Hence the rotating sprinkler is considerably more efficient from a water conservation point of view, for it applies a larger amount of water with about the same total loss by evaporation as from the overhead irrigation system. Physically the smaller drops and finer spray from the overhead irrigation system would tend to promote more rapid evaporation.

The figures for the increment of evaporation shown in Table 1 for August 17, 19, 20, and 27 are very interesting by implication. They show that as the distance downwind in the irrigated area increases, the amount of evaporation into the air becomes less. The greatest increase in moisture will occur in the first few meters within the irrigated area. Thereafter, the moisture increment becomes smaller with increasing distance into the irrigated area and will finally drop to almost zero when the air approaches saturation. Through how wide a distance this "border effect", the rapid increase in moisture content of the air as it begins to pass into an irrigated area, is experienced depends on meteorological conditions as well as on the amount of irrigation. From the figures given here it appears that only in the first 40 m within the irrigated area is there much gain in moisture in the air. The figures thus indicate that less water would be lost in an irrigation project if the size of the field to be irrigated was made as large as possible.

It should be re-emphasized that these calculations are only rough approximations of what is actually occurring in the lower atmosphere. The several assumptions that have been made, plus the various unknowns approximated, place limitations on the usefulness of the results. The assumption that 7 m is high enough to be in the homogeneous air over the spray may not be exact. Actually some vertical transport of moisture out of the volume considered between the upwind and downwind observation points takes place. For the calculation of mean wind velocity, a logarithmic distribution of wind velocity with height was assumed(5). The value assumed for the final saturated equilibrium temperature is only approximate, for the cooling of the air by heat transfer and evaporation proceeds simultaneously and will actually result in a slightly lower temperature than this. Finally the assumption that all the air in the volume passing through the spray reaches saturation and even the actual size of the volume of air to be considered are rough approximations. They may be justified here for they will give maximum evaporation values and hence clearly indicate the small scale magnitude of the evaporation from the irrigation spray. Certainly the diurnal fluctuations in this type of evaporation are so small that they can be neglected.

SUMMARY AND CONCLUSIONS

In this paper, data in the form of dew-point temperatures both to the windward and leeward of irrigation spray has been presented. *(Continued on page 348)*

How to Maintain a Thermocouple at Wet-Bulb Temperature

By H. D. Bruhn
MEMBER A.S.A.E.

IN CROP-DRYING research considerable difficulty has been experienced with hygrothermographs in accurately recording relative humidity of air. Usually there is dust present which interferes with the accuracy of many instruments. The hair element hygrothermograph at best is not too accurate even when calibrated for a given range, and moving the instrument from the calibrating laboratory to a remote installation or changing the range of operation often causes inaccuracy.

Where a recording potentiometer is available, a rugged, rather accurate and fairly simple device to indicate and record wet-bulb temperature can be assembled from readily available and comparatively inexpensive equipment.

This apparatus, shown in the accompanying illustration, consists of a very small, electric-motor-driven blower (50 to 60 cfm), an aspirator bottle, and suitable rubber stoppers, wicks and thermocouples. Single-hole rubber stoppers are used to partially close the openings in the aspirator bottle. The single-hole stopper at the top of the bottle acts as an air vent and another single-hole stopper, placed in the lower opening of the bottle, equipped with a tapered wick drawn through the hole in the stopper, regulates the flow of water from the bottle which maintains the wet thermocouple.

A two-liter bottle has been found to hold an ample supply of water for a one-week period, under most conditions. The rate of flow of water can be adjusted by moving the tapered wick either in or out, or a tapered wooden plug can be inserted beside the wick if straight wicking material is used. The blower supplies a constant blast of air over the portion of the wick which extends from the stopper. A thermocouple is wrapped into this portion of the wick.

Through the use of a recording potentiometer, a continuous wet-bulb reading is obtained. The corresponding dry-bulb reading can easily be obtained by mounting another dry thermocouple directly in front of the blower. Since these units are rather inexpensive to construct, they can be placed in numerous locations where it is desired to determine the relative humidity, and they can be connected by long leads to a multiple-point recording potentiometer. With automatic stepping switches on the recording potentiometer, the number of thermocouples used can be greatly increased, thereby making it possible to record the wet- and dry-bulb readings on any reasonable number of these units.

Theoretically, of course, it would be desirable to mount both the wet and dry thermocouples in the air stream entering the fan. However, when the equipment described above is used in connection with a potentiometer calibrated to not less than 1 F intervals, the error caused by mounting the thermocouples in the blower discharge is imperceptible. Dust accumulating on the wick may also cause an error; however, in actual field work a small amount of dust had no noticeable effect.

Where the rate of drying is high, a short, thick wick should be used and the hole in the rubber stopper should be large enough to allow a rather fast rate of water flow. Where the evaporative rate is low and the temperature of the water in the bottle might cause inaccuracy in fluctuating temperature readings, the rate of water flow should be low and the length of the wick should be increased.

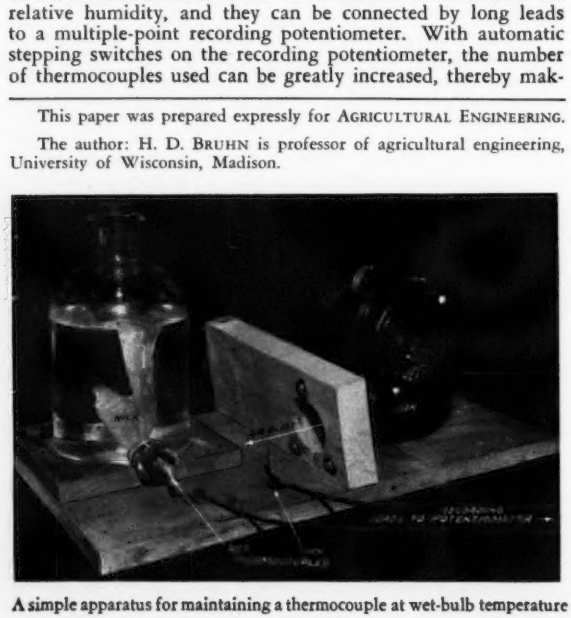
The aspirator bottles are common chemical laboratory equipment.

Any small electric fan can be used. However, the blower-type unit can readily be set so the major portion of its discharge flows directly over the thermocouples. The type of blower which is commonly used to supply draft on oil-burning water heaters has the advantage of being built for long periods of operation, "long hour service", and since the motor is completely enclosed, it is not seriously affected either by rain or dusty conditions and, in turn, is less of a fire hazard.

Thus, through the application of an old principle and the assembly of readily available and rather inexpensive parts, the sensitive portion of a piece of rugged and fairly accurate apparatus to determine relative humidity is easily assembled.

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

The author: H. D. BRUHN is professor of agricultural engineering, University of Wisconsin, Madison.



A simple apparatus for maintaining a thermocouple at wet-bulb temperature

Evaporation from Irrigation Sprays

(Continued from page 347)

Use has been made of these data in the calculation of evaporation from the irrigation spray and the moist soil and vegetation surface.

Two somewhat similar methods of computation give values for evaporation from the spray and moist soil of from 4 to 30 per cent of the water applied.

The actual observations and evaporation computations suggest that from a water conservation point of view:

1 The application of water by irrigation should occur as rapidly and in as large quantities as is economically possible to prevent undue evaporation.

2 The size of the irrigated area should be large to take advantage of the fact that less water is evaporated into the air as the size of the irrigated area increases.

REFERENCES

1 Christiansen, J. E.: Irrigation by Sprinkling, AGRICULTURAL ENGINEERING, vol. 18, no. 12, pp. 533-538 (Dec. 1937).

2 Matson, Howard: More Production from Improved Irrigation Practices, AGRICULTURAL ENGINEERING, vol. 24, no. 4, pp. 119-122 (Apr. 1943).

3 Powers, W. L.: Thirty Years of Supplemental Irrigation Studies AGRICULTURAL ENGINEERING, vol. 21, no. 8, pp. 311-312 (Aug. 1940)

4 Staebner, F. E.: Supplemental Irrigation in Humid Areas, AGRICULTURAL ENGINEERING, vol. 18, no. 4, pp. 165-168 (Apr. 1937).

5 Thornthwaite, C. W.: Determining the Wind on the Soldier, The Climate of the Soldier, Part IV, Environmental Protection Series No. 124, Office of the Quartermaster General, Research and Development Branch (Feb. 1949.).

6 Thornthwaite, C. W.: Micrometeorology of the Surface Layers of the Atmosphere. Interim Report, no. 6, April 1 to June 31, 1949, Johns Hopkins University, Laboratory of Climatology, Seabrook, N. J. (1949).

The Application of Fluidization to Conveying Grain

A Progress Report

By A. D. Longhouse, D. P. Brown, H. P. Simons and C. W. Albright

MEMBER A.S.A.E. JUNIOR MEMBER A.S.A.E.

A LOW-PRESSURE fluidization mechanism was recently developed by the Bureau of Mines in cooperation with the West Virginia Engineering Experiment Station as a part of their work on the gasification of pulverized coal. This pneumatic feeder, which was designed and built by C. W. Albright* et al, should be applicable in moving any finely divided solid.

When an interest in this equipment for agricultural purposes was expressed, it was made available to us for a limited period to test its possibilities for conveying whole grain. Wheat was selected for test because of its plentiful supply at the time the experiments were conducted. It is believed that any other small grain would have served equally well.

A diagram of the mechanism is shown in Fig. 1. A 10-in steel pipe 10 ft long was used as the fluidization chamber. Wheat was charged into the apparatus through the funnel at the top of the fluidizing chamber until it was about one-half full. Compressed air entered at the bottom of the chamber, through a fritted glass plate, and fluidized the wheat. Complete fluidization of the column did not appear necessary for whole grain, such as wheat, because air flowed readily through the voids making local fluidization at the outlet possible.

This paper was presented at the winter meeting of the American Society of Agricultural Engineers at Chicago, Ill., December 1949, as a contribution of the Farm Structures Division.

The authors: A. D. LONGHOUSE and D. P. BROWN, respectively, head and assistant professor in agricultural engineering department, West Virginia Agricultural Experiment Station, and H. P. SIMONS and C. W. ALBRIGHT, chemical engineering department, West Virginia Engineering Experiment Station, Morgantown.

*Albright, C. W., Holden, J. H., Simons, H. P., and Schmidt, L. D.: Pneumatic Feeder for Finely Divided Solids. *Chemical Engineering*, 56, p. 103 (June).

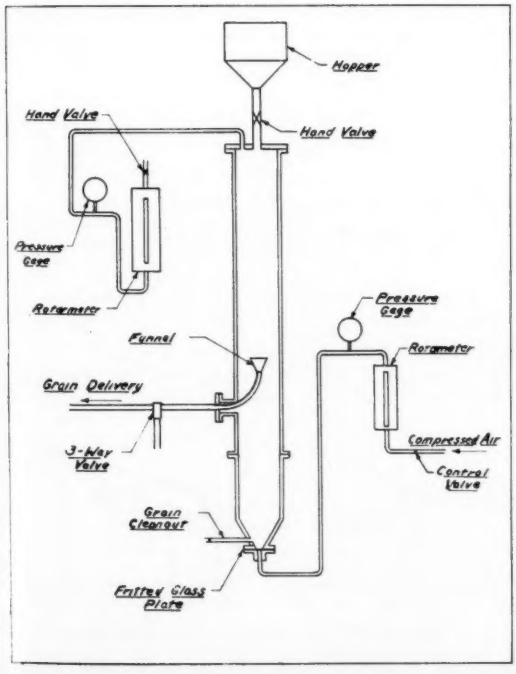


Fig. 1 Schematic diagram of a low-pressure fluidization apparatus

Albright found that complete fluidization was necessary for fine coal; therefore it seems reasonable to assume finely ground feed must likewise be fully fluidized before satisfactory results can be obtained. Where complete fluidization is necessary, the fluidizing air can be adjusted to the required rate for the different kinds of grain or ground feed. Different densities require different fluidizing rates. These rates can be measured by a rotameter connected in at the top of the fluidizing chamber. This is to be investigated further and will be reported in a later paper.

The wheat line, or delivery pipe, was blown out by admitting air through the 3-way valve, and the wheat flow was started by turning the valve to the straight-through position.

The wheat line in all of these tests was a 1-in tube about 75 ft long have 3 right-angle turns (4-in radius) and one U turn (1-ft radius) at the end to facilitate weighing conditions at the scale. Weight ratios of wheat to air of about 20:1 were regularly passed through the wheat line when no funnel was used on the line in the fluidizing chamber. Albright obtained weight ratios of coal to air up to 200:1 regularly. Similar ratios may be obtained for ground feed but preliminary tests indicated such ratios can not be obtained for whole grain.

Tests on coal indicated an inverted funnel was necessary to prevent air bubbles from forming where the coal entered the delivery line in the fluidizing chamber. Similar tests were made with wheat. However, in these tests comparisons were made using upright funnels of 2-, 3-, and 4-in diameter. Results of these tests are shown in Table 1. *(Continued on page 352)*

TABLE 1 SUMMARY OF DATA ON WHEAT USING 1-IN DELIVERY PIPE 75 FT LONG

Funnel Size	Pressure, psig	Air flow cfm	Lb. air/ min	Lb. grain/ lb air	Ton/hr	Hp/ton	Hp/hr
None	5	14.00	1.54	22.88	1.040	.350	.36
	8	21.50	2.46	19.58	1.450	.660	.98
	10	23.50	3.14	16.77	1.590	.870	1.39
2 in	17	10.17	1.64	25.90	1.275	0.901	1.15
	21	16.44	2.94	20.15	1.818	1.391	2.53
	24	19.00	3.74	18.40	2.067	1.678	3.47
3 in	16	12.50	1.95	23.65	1.383	0.976	1.35
	20	17.50	3.09	20.10	1.866	1.339	2.50
	24	19.46	3.82	18.20	2.091	1.707	3.57
4 in	19	14.87	2.55	21.50	1.642	1.218	2.00
	22	16.08	3.00	21.25	1.914	1.374	2.63
	24	19.08	3.75	18.72	2.109	1.654	3.49

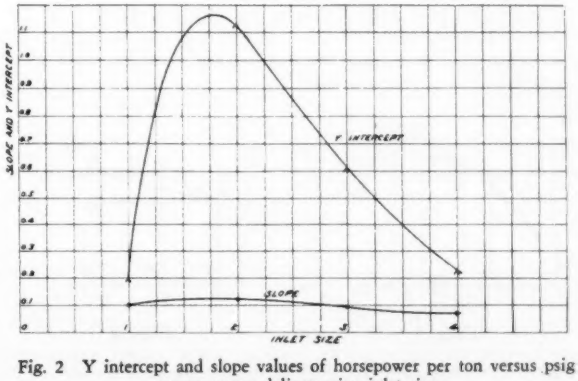


Fig. 2 Y intercept and slope values of horsepower per ton versus psig curves versus delivery-pipe inlet size

The Application of the Profit-Water Curve to Irrigation Projects

By Hitoshi Fukuda

CLYDE, Gardner, and Israelsen analyzed* three problems regarding the efficient use of irrigation water. Their original data included experimental curves representing the yield per acre, y, in terms of the amount of water, w, applied. They computed the net income per acre in terms of the yield and the water used and equated its derivatives with respect to w to zero and thus obtained the amount of water that would make this income a maximum.

Expanding the work of these men, this paper presents a new problem and its graphical solution, also the analytical proof. Instead of limiting the discussion to a single crop, the more general case in which two or more crops are involved is discussed. In many arid regions where there is insufficient water for the land available when a particular crop is involved it may be possible to utilize this land more efficiently by planting more than one crop. The problem then arises as to how much water will be applied per acre for each of the various crops in order to obtain maximum profits.

In the following consideration of the profit curve and its application to the case in which there is a limited water supply, the same notation has been used here as in the paper referred to above, namely,

a = price per ton of the crop on the farm, which is the market price minus the cost per ton for hauling. The cost of hauling varies with the yield and therefore could not be counted in b

b = cost per acre for plowing, seeding, fertilizing, tilling, taxes, rental value and such other costs as are proportional to the acreage

c = cost of water

w = number of acre-inches of water applied per acre

Q = total number of acre-inches of water applied on the total area

y = yield in tons per acre

A = total irrigable area in acres.

As y is a known function of w experimentally, the net profit per acre is $ay - b - cw$.

In this paper the gross profit Z will be defined as follows:

$$Z = ay - b \qquad [1]$$

This is because it is convenient to compare the profits with one another when two or more different crops are under consideration. (When a and b vary with w, this conception will also be applicable.)

Now let only x acres in the total area A be irrigated. The net profit will be

$$P(w) = x\left[Z(w) - cw\right] \qquad [2]$$

1 Take the case with a sufficient water supply. It is profitable, to be sure, to irrigate the total area, namely,

$$x = A = \text{a constant},$$

For the maximum P, the derivative of P with respect to w is zero,

$$dP/dw = A(dZ/dw - c) = 0 \qquad [3]$$

If we follow the $(Z\text{-}w)$ curve until we find a point where the slope of the tangent is equal to c, that point gives the value of w for the maximum profit per acre (w_{max} shown in Fig. 1). It will certainly be a loss to use more water than w_{max} even if an abundant water supply can be obtained.

2 Now consider the case in which there is insufficient water. From above notations, mean w, may be given by

$$Q/A = w_0 \qquad [4]$$

At first, this paper does not consider the water cost because it may be necessary to consider the cost only when w_0 exceeds w_{max}. In cases in which w_0 is less than w_{max}, we shall always use the total water Q and such water cost may be maintained constantly.

(A) Single crop. A case in which a tangent from the origin to the $(Z\text{-}w)$ curve can not be drawn, and its curve is always convex upward ($d^2Z/dw^2 < O$).

Case 1. It is more profitable to irrigate the total area with water w_0 than to do a part with w_1, the remainder with w_2. The reason may be explained as follows (Fig. 2): When an area Ax with w_1 and $A(1-x)$ with w_2 will be irrigated ($O \leqq x \leqq 1$), the ratio of the two areas $x/(1-x)$ may be determined at any values w_1, w_2. As the total water equals Aw_0, we obtain

$$w_1 Ax + w_2 A(1-x) = w_0 A \qquad [5]$$

$$x = \frac{w_2 - w_0}{w_2 - w_1} \qquad 1 - x = \frac{w_0 - w_1}{w_2 - w_1}$$

From Fig. 2 we know $w_0 \geqq w_1$ when $w_2 \geqq w_0$. $w_1 = w_0$ of course when $w_2 = w_0$. The total net profit (without water cost) in this case is shown by the following formula:

$$P = AxZ(w_1) + A(1-x)\,Z(w_2)$$

and therefore $P/A = \dfrac{w_2 - w_0}{w_2 - w_1} Z(w_1) + \dfrac{w_0 - w_1}{w_2 - w_1} Z(w_2)$

$$= \frac{B'C'}{AB'} AA'' + \frac{AC'}{AB'} BB'' = \frac{B'C'}{AB'} AA'' + \frac{AC'}{AB'} (AA'' + BB'')$$

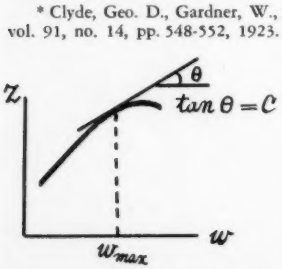


FIG. 1

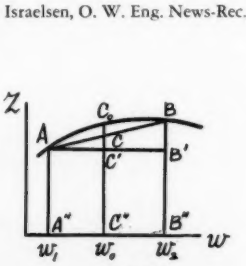


FIG. 2

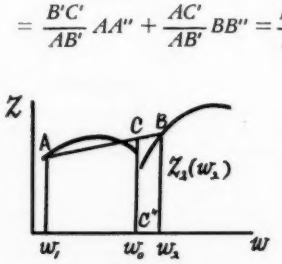


FIG. 3

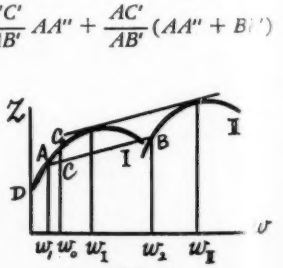


FIG. 4

Fig. 1 Profit-water curve for single crop • Fig. 2 Profit-water curve for single crop, to which a tangent from the origin cannot be drawn • Fig. 3 Profit-water curve for two crops • Fig. 4 Profit-water curve for two crops in case of $O < w_0 < w_1$

This paper was prepared expressly for AGRICULTURAL ENGINEERING.

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* Clyde, Geo. D., Gardner, W., and Israelsen, O. W. Eng. News-Rec., vol. 91, no. 14, pp. 548-552, 1923.

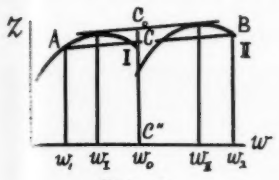


FIG. 5

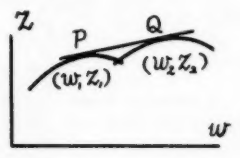


FIG. 6

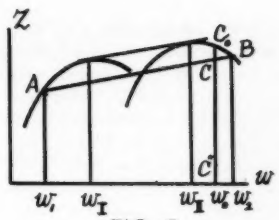


FIG. 7

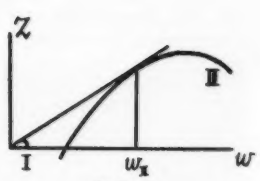


FIG. 8

Fig. 5 Profit-water curve for two crops in case of $w_I < w_o < w_{II}$ • Fig. 6 • Fig. 7 Profit-water curve for two crops in case of $w_{II} < w_o$ • Fig. 8 Profit-water curve for single crop, to which a tangent from the original can be drawn

$$= AA'' + \frac{AC'}{AB'} BB' = C'C'' + CC' = CC'' \quad [6]$$

On the other hand, when the total area is irrigated with w_o the net profit is

$$P_o/A = Z(w_o) = C_oC'' \quad [7]$$

As the curve $Z = Z(w)$ is convex upward, C is never above C_o at any values w_1, w_2. In particular, when $w_1 = w_o$ (or $w_2 = w_o$), C coincides with C_o.

This means that it is the most profitable to irrigate the total area with w_o. For the same reason it is not profitable to irrigate many small parts of the area with different amounts of water.

Case 2. When w_o exceeds w_{max} (here $dZ/dw = c$), it is of course profitable to irrigate the total area with w_{max}.

To explain cases 1 and 2 analytically, consider the total area A being divided into small parts,

$x_1A, x_2A, \ldots x_nA$. $(x_1 + x_2 + x_3 \ldots + x_n = 1. \quad O \leqq x_i \leqq 1, i = 1, 2, \ldots n)$, the various parts being irrigated with w_1, w_2, $w_3 \ldots w_n$ per acre, respectively. Then the net profit (without water cost) from any one part x_iA by Taylor's expansion becomes,

$$P_i = x_iAZ(w_i) = Ax_i \Big] Z(w_o) + (w_i - w_o) \left(\frac{dZ}{dw}\right)_{w=w_o} + \frac{(w_i - w_o)^2}{2} \left(\frac{d^2Z}{dw^2}\right)_{w=w'_i} \Big] \quad [8]$$

where w'_i is any value between w_o and w_i. The total net profit is,

$$P = \sum_{i=1}^{n} P_i = AZ(w_o)\Sigma x_i + A\left(\frac{dZ}{dw}\right)_{w=w_o} \Sigma x_i(w_i - w_o) + A\Sigma x_i \frac{(w_i - w_o)^2}{2} \left(\frac{d^2Z}{dw^2}\right)_{w=w'_i} + \ldots . \quad [9]$$

It is apparent that $\Sigma x_i = 1$, $\Sigma x_i w_i = w_o = w_o \Sigma x_i$, $\Sigma x_i(w_i - w_o) = O$, and we therefore obtain

$$P = AZ(w_o) + A\Sigma x_i \frac{(w_i - w_o)^2}{2} \left(\frac{(d^2Z)}{dw^2}\right)_{w=w'_i} = P_o \text{ plus a negative} \quad [10]$$

inasmuch as $x_i \geqq O, (w_i - w_o)^2 \geqq O, d^2Z/dw^2 < O$.

The second term in the right-hand member of equation [10] is always negative except when $w_i = w_o$, i.e., when the total area is irrigated uniformly with w_o. Therefore P becomes maximum and equals P_o when $w_i = w_o$.

(B) Two crops, I, II. (A common tangent can be drawn.)

Now consider the case in which the mean amount of water is w_o and crops I, II are irrigated with water w_1, w_2 respectively. Following the same reasoning as in (A), the net profit (without water cost) will become as illustrated in Fig. 3,

$$P/A = CC'' \quad [11]$$

and this profit will vary with w_o. Now the water w_I and w_{II} of Fig. 4 corresponds to tangent points of curves I and II, respectively.

Case 1. In the case where $O < w_o < w_I$.

In Fig. 4, however, w_1 moves in a range $O < w_1 < w_o$ (the point A moves on an arc DC_o) and the point C is always lower than the point C_o except when the points A and C coincide with C_o. This means the cultivation of crop I but not crop II. Consequently in this case it is profitable to irrigate the total area with w_o and to grow crop I

Case 2. In the case where $w_I < w_o < w_{II}$.

In Fig. 5, let C_o be a crosspoint of the common tangent and the line CC''. Sliding the point A on the curve I, B on the curve II, the point C will take the highest position when the line AB becomes the common tangent. In this case C coincides with C_o. Then as $w_1 = w_I$, $w_2 = w_{II}$, it will be best to irrigate crop I on the area $Ax = A(w_{II} - w_o)/(w_{II} - w_I)$ with the water w_I per acre, crop II on the area $A(1-x) = A(w_o - w_I)/(w_{II} - w_I)$ with water w_{II} per acre (see equation [5].

To prove this analytically, secure the maximum value of the right-hand member of the following equation:

$$P/A = xZ_1(w_1) + (1-x)Z_2(w_2) \quad [12]$$

Here x, w_1, w_2 are variables but as between them there is a fixed relation:

$$Q/A = w_1x + w_2(1-x) = w_o = \text{a constant} \quad [13]$$

any two of the three being regarded as independent variables.

The values of x, w_1, w_2 that will maximize P/A in equation [12] will coincide with the values required to maximize the function,

$$f(x,w_1,w_2,\lambda) = xZ_1(w_1) + (1-x)Z_2(w_2) - \lambda \left[w_1x + w_2(1-x)\right] \quad [14]$$

in which λ is Lagrange's multiplier. The conditions in this case are:

$$\partial f/\partial x = Z_1(w_1) - Z_2(w_2) - \lambda(w_1 - w_2) = O \quad [15]$$

$$\partial f/\partial w_1 = x\, dZ_1/dw_1 - \lambda x = O \quad [16]$$

$$\partial f/\partial w_2 = (1-x)\, dZ_2/dw_2 - \lambda(1-x) = O \quad [17]$$

If x is not equal to O, x is not equal to 1, we obtain from equations [15], [16], [17],

$$dZ_1/dw_1 = dZ_2/dw_2 = \frac{Z_2(w_2) - Z_1(w_1)}{w_2 - w_1} = \lambda \quad [18]$$

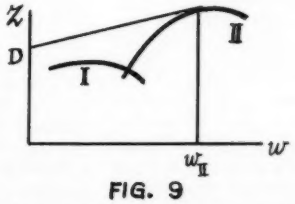


FIG. 9

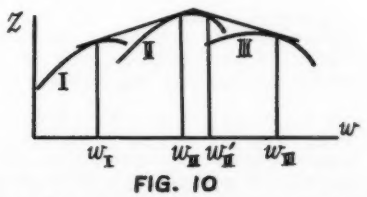


FIG. 10

Fig. 9 Profit-water curve for two crops, to which a common tangent can not be drawn • Fig. 10 Profit-water curve for more than two crops

Now let P, Q be points with coordinates (w_1, Z_1), (w_2, Z_2), respectively, (in Fig. 6), dZ_1/dw_1, dZ_2/dw_2 being the slopes of the curves, I, II at the points P, Q, respectively, and $(Z_2-Z_1)/(w_2-w_1)$ the slope of the line PQ. These three slopes will coincide only when the line PQ becomes a common tangent of curves I and II. And, as $x = (w_{II}-w_o)/(w_{II}-w_I)$ when $O \leqq x \leqq 1$, this proof will be applicable only when $w_I < w_o < w_{II}$.

Case 3. In the case where $w_{II} < w_o$.

By the same reasoning as Case 1, it is preferable to cultivate the crop II on the total area with w_o as given in Fig. 7. And in case $w_o > w_{max_2}$, w_{max_2} will of course have to be adopted.

(C) Application of (B) to the case of one crop. (A tangent from the origin can be drawn to the $(Z\text{-}w)$ curve).

Let the irrigable crop be II, and let us consider an imaginary crop I, given in Fig. 8, which has a very small Z near the point $w = O$. Then the case (B) will be applicable inasmuch as a common tangent of the curves I, II is to coincide with a tangent from the origin to curve II, and the tangent point on the curve I corresponds to the origin (here $w_I = O$).

By putting $w_I = O$ in the results of (B).

Case 1. In the case of $O < w_o < w_{II}$, the crop II is to be cultivated only on the area Q/w_{II} with w_{II} and the remainder is to be left as it is.

Case 2. In the case of $w_o > w_{II}$, the crop II is to be irrigated on the total area with w_o. If $w_o > w_{max_2}$, the water to be used is, of course, w_{max_2}.

(D) Two crops I, II. (A common tangent can not be drawn).

In the case in which the curve I lies under a tangent from the point D to the curve II, as indicated in Fig. 9, it will be admissible to consider the crop I as having a very small Z near the point $w = O$, corresponding to (C). Therefore, the case of (B) will be applied here also.

Case 1. In the case of $O < w_o < w_{II}$, the crop II is to be cultivated only on the area Q/w_{II} with w_{II} and the crop I on the remainder with no water.

Case 2. In the case of $w_o > w_{II}$, the crop II is to be cultivated on the total area with w_o. If $w_o > w_{max_2}$, the water to be used is, of course, w_{max_2}. Here by producing the curve I to the axis Z the position of the point D will be estimated on that axis.

(E) More than two crops.

As in the case (B) it will be stated from Fig. 10 as follows:

Case 1. In the case of $O < w_o < w_I$ only the crop I.

Case 2. $w_I < w_o < w_{II}$, two crops I, II.

Case 3. $w_{II} < w_o < w'_{II}$, only the crop II.

Case 4. $w'_{II} < w_o < w_{III}$, two crops II, III.

The same relation applies correspondingly to the following parts, and the amount of water and irrigable area are to be indicated by the same formula as in the case (B).

Up to this point the values a, b and c have been considered as constants, whereas in many cases, as pointed out in the paper referred to, they are variable and dependent on w, but even in this case we may no doubt safely say that many crops can be compared with one another.

SUMMARY

In this paper treating the combination of many irrigable crops on a given land, the irrigable area and required amount of water for each crop from the most economical standpoint, taken on the whole, were discussed and determined. The case with limited water supply was always considered by using the profit-water curve which was to be obtained experimentally.

The Application of Fluidization to Conveying Grain

(Continued from page 349)

Equipment Limitations. It should be kept in mind that the equipment used was designed for finely ground coal and not for whole wheat. Further, the equpment was on a loan basis for four weeks; consequently no major changes could be made in its design. The principal purpose of these tests was to determine whether or not low-pressure fluidization could be used successfully to convey grains.

The range over which data could be obtained at low pressure was limited by the rotameter capacity of 25 cfm. Similarly air pressures above 20 psig (pounds per square inch gage pressure) were difficult to hold which may have affected the accuracy of the data of the higher pressures.

Test Results. Preliminary tests indicate whole wheat can be transported with ease through a 1-in pipe 75 ft long, either vertically or horizontally or both. It appears this distance can be increased considerably, but equipment limitations prevented further tests with larger and/or longer pipe. As soon as a new installation can be made more exhaustive tests will be conducted.

The mechanism required relatively low pressures in the fluidizing chamber when funnels were not used, but the air velocity was greater (Table 1). The limited capacity of the rotameter prevented further studies here. When 2-, 3-, and 4-in funnels were added, the pressure requirements increased and the air velocity decreased (Table 1). Again equipment limited operations above 24 psig. The effective range of operation for any of the funnels used can be increased by using a larger air compressor and air measurement equipment.

When no funnel was used, successful operation could not be obtained below 5 psig. This minimum pressure was considerably higher when a funnel was added (Table 1).

Horsepower requirements were substantially lower when no funnel was used. However, the rate of flow per hour was also lower when no funnel was used. When no funnel was used the horsepower requirements per ton ranged from 0.35 hp at 5 psig to 0.87 hp at 10 psig; when a 2-in funnel was used the horsepower per ton increased to 0.9 hp at 17 psig up to 1.68 hp at 24 psig. Similar results were obtained for the 3- and 4-in funnels (Table 1).

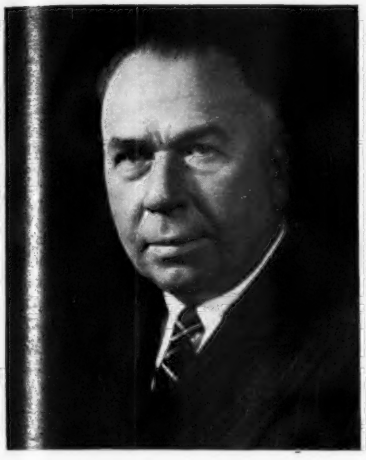
For any given funnel (or no funnel) the ratio of pounds of wheat to pounds of air is best at the lowest pressure at which the mechanism will operate (Table 1). This critical pressure is easily detected because a change of one pound pressure at this point will cause uneven flow and plugging.

Using a 1-in wheat line, grain-air ratios of 20:1 are regularly obtained. An inspection of Fig. 2 will indicate that the inlet opening size, within the range of 1 to 4 in, did have some effect on the slope of the horsepower per ton vs. gage pressure curves. The greater slope of the curve for the 2-in opening would increase the value of the Y intercept as is shown by the Y intercept vs. inlet size curve. These curves indicate that a funnel of size intermediate between no funnel and a 2-in funnel would give the best grain-air ratios for a 10-in fluidizing chamber using a 1-in delivery line.

CONCLUSION

The results of this preliminary study support original belief that grain, either whole or ground, can be conveyed satisfactorily as a fluid. The convenience and ease of operation of the system are greatly in its favor, especially on farms where a considerable amount of grain needs to be moved within a building or transported from one building to another. The initial cost and maintenance should not be excessive because most of our larger farms either already have or could well use an air compressor of sufficient size to operate the fluidizer.

The 1950 A.S.A.E. Gold Medalists



A. P. YERKES

The American Society of Agricultural Engineers awarded the Cyrus Hall McCormick Medal to Arnold P. Yerkes and the John Deere Medal to Roy B. Gray at Washington, D. C., on June 21

R. B. GRAY

IN THE selection of Arnold P. Yerkes to receive the Cyrus Hall McCormick Gold Medal for 1950, the Jury of Awards of the American Society of Agricultural Engineers again has chosen a man whose distinction cannot be defined by a few notable achievements nor by intense specialization in a narrow field. Again it is a tribute to a long career of endless energy, firm convictions, and broad horizons with agricultural engineering always at their center.

His origin and his orientation were of the soil. It was on a farm near Davisville, in Bucks County, Pennsylvania, that he was born February 8, 1885, the son of Arthur Watts and Margaret (Hallowell) Yerkes. As a boy, sharing the hard work and meager rewards of that farm, barred by its topography from efficient use of power and machinery, he developed his lifelong philosophy and purpose that the results of human toil must be multiplied by application of science, especially through engineering.

As to formal education, it is noted only that he was graduated from township school and from business college. If he has academic degrees or distinctions, neither he nor his friends have bothered to mention them. They speak rather of his insatiable appetite for ever more and ever new knowledge, his private studies, and ultimately his repute as a veritable walking encyclopedia.

Early employment included three years each in the office of the Inspector of Ordnance, U. S. Army, Midvale Steel Works, and in the Small Arms and Equipment Division, preceded by shorter periods with the Franklin Institute of Pennsylvania and the Philadelphia and Reading Railway.

In those short and early years with Ordnance he devised a correspondence system to supersede an old and wasteful method of writing and filing. He holds this a high light of his career, not as a great invention or as a piece of agricultural engineering, but because in forty years of steady use it has saved millions of dollars in government expense and countless hours of human attention.

Then, in 1912, Mr. Yerkes entered the Office of Farm Management, U. S. Department of Agriculture, starting as a scientific assistant in agronomy, Farm Equipment Division. Presently he was assistant agriculturist, then agriculturist, and for three years before he left in 1918 he headed the Division. Equipment research at that time consisted largely of tractor investigations in which a tabulating system of his devising cut time and expense so greatly that it was adopted in several other divisions and continued in use until mechanical tabulation was perfected.

During World War I, he served as assistant to Junius F. Cook, Farm Equipment Administrator, in allocation of materials to the industry. *(Continued on page 354)*

IN THE selection of Roy B. Gray to receive the John Deere Gold Medal for 1950, the Jury of Awards of the American Society of Agricultural Engineers has indeed designated a man whose long and varied career has increasingly concentrated on "application of science and art to the soil."

Born June 10, 1884, at Hampton, Iowa, Roy B. Gray was the son of Henry and Alice Gray. His education in the Iowa schools was climaxed by graduation from Iowa State College in 1909 with the B.S. degree in electrical engineering, and a year later with a duplicate degree in agricultural engineering. In 1931 his alma mater conferred the professional A.E. degree on him.

Besides being active in track athletics in college, he was active in football as a tackle; in fact, it has been alleged that he was more interested in football than in electricity. There is a legend, possibly apocryphal, that he came to be known as "Muscles," and that for reasons mainly physical he was recruited into the department of agricultural engineering as a means of cranking the behemoth tractors of those days. Anyway, he became Iowa's second graduate in agricultural engineering.

During the decade 1910-1920 he was an experimental tractor engineer with the International Harvester Company, mostly in foreign countries including Canada, England, Germany, France, Austria, Italy, Romania, and South Africa. However, there was a hiatus when in 1916-17 he had charge of a tractor assembly depot and a military tractor school in England, and in 1918 was technical advisor to the British army on agricultural tractors in France and to the Italian army in Italy.

In the 1921-24 period he was in charge of the department of agricultural engineering at the University of Idaho. In 1925 began his present connection with the U. S. Department of Agriculture where he is head of the Division of Farm Machinery in the Bureau of Plant Industry, Soils, and Agricultural Engineering. Immediately he began "digging in" to the soil with a project on fertilizer placement machinery.

But then came the invasion by the European corn borer, and Mr. Gray was assigned to an action program, extending from 1927 to 1931. It was a holding operation, and a huge task of organization and cooperation among various agencies of the federal government, the states and Canada. He directed the research and design work as it involved machinery for borer control. It included destruction by burial, through proper plows, plow attachments, and plowing; burning, by machines that had to be developed swiftly from scratch; and by machine treatment of stalks during harvest or otherwise.

In 1931, when agricultural engineering was given separate bureau rank in the USDA, Mr. Gray was put in charge on

farm machinery and equipment. Among many activities he has directed, a major opus was related to the planning and establishment of the tillage machinery laboratory at Auburn, Ala. Here, in what is probably the world's most completely controlled, comprehensive array of full-scale soil samples, can be studied practically every relation between the various soils and every machine element which they touch.

Also under his direction is the pest and plant disease control laboratory at Toledo, Ohio. What with the length of his career and the breadth of his responsibility, there is hardly a farm machine or operation with which he has not been concerned. Listing many such, his former chief, the late S. H. McCrory, made special mention of Mr. Gray's guidance in the development of new machines for specific tasks, such as harvesting pyrethrum, hulling tung nuts, harvesting sweet potato vines, and lifting down cornstalks (an attachment for a corn binder). In 1936 he spent several months observing farm machinery and farm electrification developments in seven countries of Europe.

As an author, he has been more technical than popular, more authoritative than prolific. To be sure, his name appears on a few circulars and farmers' bulletins. In contrast are seven articles in the current Encyclopedia Britannica, articles in several USDA Yearbooks, preparation or revision of a variety of department publications and papers published from time to time in AGRICULTURAL ENGINEERING.

Mr. Gray has been a member of the American Society of Agricultural Engineers since 1920. He was chairman of its Power and Machinery Division in 1933-34, and of the Washington, D. C., Section in 1941-42. He has served on no less than nine of its technical committees. In allied fields he has been chairman or member of committees on farm production and processing equipment of the Farm Chemurgic Council, motor fuels of the American Society for Testing Materials, application equipment of the Agricultural Insecticide and Fungicide Association, and farm equipment requirements of the Marshal Plan, having been appointed in 1948 to an ECA farm machinery mission to study farm machinery needs in some ten European countries.

In addition he has served as consultant to still other technical committees in such organizations as the Farm Bureau and the American Petroleum Institute. He was a member of the Interbureau Committee of the USDA which estimated farm machinery needs for 1942 and made recommendations to the Office of Production Management. Other memberships include the Society of Automotive Engineers, the Congregational Church, and Sigma Alpha Epsilon Fraternity.

Even in his avocations Mr. Gray includes the soil. According to one of his associates, his "garden is always better than the neighbors' — his radishes are earlier, his tomatoes are rounder, and his spinach has more vitamins." Languages, once a necessity, remain an abiding interest. On this point it is alleged:

"Unfortunately, it is apparently the case that the words of a foreign language most easily learned and longest remembered are the invectives and cuss words. Gray, with the resources of six languages at his command, can really tell a man off. For this reason it is necessary to keep a plate glass top on his desk in order to save the varnish."

This talent, if actual, is all the more amazing in a man whose usual manner is gentle almost to the point of diffidence, whose smile and greeting are the essence of friendliness. More credible is his accomplishment as a bass singer, the "spark plug of the male quartet of the Divisions of Agricultural Engineering, singer of leading roles in departmental and community presentations."

Mr. Gray's wife is the former Carolyn J. Skilton. They have a daughter, Virginia, besides Mrs. Gray's sons, Jack and George Skilton.

Award of the John Deere medal to Mr. Gray recalls an earlier honor conferred on him by the French government, the decoration of "Officer du Merite Agricole." The letter from the Minister of Agriculture said it was in recognition of services rendered to French agriculture.

A. P. Yerkes—1950 McCormick Medalist

(Continued from page 353)

When he joined the International Harvester Company in 1918, it was a connection destined to stand unbroken until his official retirement in February of this year. It was interrupted, however, by his appointment as dollar-a-year man, in 1942, to the Farm Equipment Section of the War Production Board, and in the following year as collaborator for the Department of Agriculture, consulting with the Food Production Administration and the War Food Administration.

For many years after joining the Harvester staff, Mr. Yerkes was editor of "Tractor Farming" and "Canadian Tractor Farming." While earning their way as advertising media for the company, they served as vehicles for the wealth of practical information, the sound philosophies, and the wisdom which he had to share with the farmers of the two countries. Through those columns Mr. Yerkes gave wide circulation to numerous agricultural engineering items, and is credited with having exerted a tremendous influence not only on power-farming practices but on the development of the tractor itself.

In 1938 he was made editor-in-chief of the Harvester advertising department, and soon thereafter, in 1940, he was given a new title in a newly created position — general supervisor of farm practice research. To at least one of his friends this seemed a case of the job growing up to fit the stature of the man and the nature of his work for many years. In that capacity he continued until his retirement this year.

Mr. Yerkes became a member of the American Society of Agricultural Engineers in 1918. He has always been active in its affairs, serving on various committees, presenting notable papers, and being chairman of the Power and Machinery Division in 1925-26 and president of the Society in 1937-38. Other professional memberships include the Soil Conservation Society of America, Friends of the Land, and the Agricultural Council of the Chicago Association of Commerce and Industry.

From its founding, he has been a moving spirit in the Farm Chemurgic Council and since 1937 has served on its board of governors. Last year he was elected one of its three vice-presidents. His contributions to its achievements are implicit in the fact that many chemurgic developments depend entirely on availablity of machines and methods for the culture, harvest and processing of agricultural materials.

Increasingly, for perhaps twenty years, Mr. Yerkes has been concerned with the so-called trace elements and their elusive vital roles in soils and in the health of plants, animals, and people. In his studies, travels, writings and speeches in this field he has ranged from the role of researcher to that of evangelist. Inevitably it dovetailed with a myriad aspects not only of agriculture and engineering, but of other arts and sciences.

Out of it all has evolved what he hopes may be the crowning achievement of his career — a project for establishment and operation of a central agricultural analytical service. Alone at first, he now has hearty cooperation of other leaders and prospect of backing by institutions of high order. As he envisions it, the service will provide the utmost in modern laboratory equipment for scientific study of soils, plants and animal tissues, all manner of feeds, fertilizers, and other substances used in agriculture. It will serve not only farmers but doctors, veterinarians, feed and fertilizer manufacturers, and educational institutions.

As an author, Mr. Yerkes has been so prolific that his writings defy compilation. During his early years with the U. S. Department of Agriculture his name appeared on eleven bulletins. In more than thirty years thereafter he has contributed major papers and popular articles in technical journals, including AGRICULTURAL ENGINEERING, to farm papers, and to the trade press. He has made radio talks and personal appearances at civic clubs, farm organizations, societies and associations ranging from agronomy to railroads.

In contrast with his many technical connections, Arnold Yerkes holds no memberships in any social, fraternal, or purely honorary organizations. His family consists of his wife, nee Rebecca Moon, and daughters, Carolyn, Virginia, and Anne.

NEWS SECTION

F. C. Fenton Becomes New A.S.A.E. President

FREDERICK C. FENTON took office as the new president of the American Society of Agricultural Engineers, June 21, at the close of the Society's 43rd annual meeting in Washington, D. C.

He has been active in the Society since 1917, when he was first elected an Associate Member. In 1928 he was elected a Member and in 1938 became a Fellow in the Society.

Like his predecessor in office, Frank J. Zink, Fred Fenton is a native of Iowa and an agricultural engineering graduate of Iowa State College. Entering as a student in 1910, he soon came under the pioneering influence of J. B. Davidson and his vision of the possibilities for engineering in agriculture.

Following his graduation in 1914 he was retained by the College to expand its agricultural engineering extension work. He resigned this position in November 1916 to undertake similar work with the University of Missouri.

Called to war service in August 1917, he spent 20 months overseas as a First Lieutenant of Artillery. His duty included service as an instructor in artillery schools at Paris and Limoges. After the Armistice he was permitted to go to England and study at Oxford University for one term.

F. C. FENTON

Back in the United States in 1919, he was recalled to his alma mater as associate professor of agricultural engineering, in charge of instruction in farm buildings. He continued in this work, with added research duties in farm buildings and home utilities, for nine years, during which time he also received his master's degree in agricultural engineering.

During the summer of 1927 he further broadened his experience with work as a draftsman in the architectural department of the Louden Machinery Company at Fairfield, Iowa.

In 1928 he was selected for his present position as professor and head of the agricultural engineering department at Kansas State College. In addition to his administrative work there as head of the department he has become a registered professional engineer, has continued his special interest in farm structures, and developed an active interest in rural electrification, serving as secretary-treasurer and project director of the Kansas C.R.E.A. His continuing attention to farm structures has been especially directed toward grain storage, wind pressures, regional research programs, and the Midwest Plan Service.

Under his influence a procession of young men have moved through employment in the agricultural engineering department, and through its undergraduate and graduate curriculums to positions of increasing responsibility in the agricultural engineering world.

In the Society he has served as chairman of the Farm Structures Division, chairman of the College Division, vice-president, councilor, first chairman of the Mid-Central Section, and almost continuously on various committees.

Other professional, honorary, and social organizations in which Mr. Fenton is a member include the American Society of Engineering Education, Sigma Xi, Alpha Zeta, Gamma Sigma Delta, Sigma Tau, Delta Sigma Rho, Phi Kappa Phi, and Theta Delta Chi.

He says that, since good fishing in Kansas is scarce, his chief recreation is golf.

In 1922 he married Doris Hays, daughter of a former Assistant Secretary of Agriculture, a graduate of Swarthmore, and teacher of English at Iowa State College. Their son and two daughters are all graduates of Kansas State College, the youngest daughter, Jane, having been a senior this year. The son, Franklin, is a chemical engineer and one daughter, Ruth Ellen, a teacher at Hull House in Chicago, recently became Mrs. John Bascom. Mr. Fenton, also, in recent months attained the distinction of being a grandfather.

From the perspective of their 28 years of married life, Mrs. Fenton appraises him as "an unassuming kindly man with a critical, clear-thinking mind and a quick-flashing wit." He brings to the presidency of the Society a thorough knowledge of its history and activities, and a keen vision of its future possibilities.

A.S.A.E. Meetings Calendar

August 28-30—NORTH ATLANTIC SECTION, University of New Hampshire, Durham

October 19 and 20 — PACIFIC NORTHWEST SECTION, Yakima, Wash.

December 18-20 — WINTER MEETING, The Stevens, Chicago, Ill.

June 18-20 — ANNUAL MEETING, Rice Hotel, Houston, Tex.

A.S.A.E. Annual Meeting Was Capital Affair

WHILE it did not quite reach the record attendance of last year's annual meeting, the 43rd annual meeting of the American Society of Agricultural Engineers set another attendance record for a non-central meeting when over 800 ASAE members, members of their families, students, and guests gathered in the nation's capitol, June 19-21.

The nation's capitol, eastern industries, individual ASAE members in the area, and the Washington (D. C.) Section of the Society in particular, acted as most gracious hosts for all those assembled to share in the great variety of professional, technical, historical, and social features of the 4½-day program. From the initial invitation to the last farewell their hospitality was exhibited by way of excellent arrangements, accommodations, entertainment, and a desire to be of service to their guests throughout the meeting.

The ladies and young people were entertained with a special program while dad was occupied with his technical sessions. Baby sitters were provided for the very young agricultural engineers and their sisters so that mother was free to enjoy her part of the program.

Throughout the meeting the interest of the press, government agencies, and foreign delegations gave repeated evidence that the profession of agricultural engineering is gaining increasing recognition and prestige. The news coverage given by both the press and radio was particularly gratifying.

In his president's annual address, retiring President Frank J. Zink challenged his colleagues to foster and promote those ideas and standards which will enhance the profession of agricultural engineering. He advocated one strong bureau of agricultural engineering to handle research in the U. S. Department of Agriculture, rather than two bureaus as had been suggested. The extremely high rate of mechanization of agricultural production during the last ten years has created many problems in the integration and use of equipment, and he said it is the Society's view that research investigations can be most economically administered through one strong central agency.

Modern farming requires more skill than any other industry, Assistant Secretary of Agriculture Knox T. Hutchinson, brought out in his address at the first general session. In a "Challenge to Service for Agricultural Engineers," Hutchinson warned that, if farmers are to continue mechanizing their operations at a healthy pace, they must have adequate returns. When prices fall too low, farmers like other businessmen, cannot afford improvements. He pointed out that many farmers are getting uncomfortably close to that position. The successful American farmer nowadays has to be an engineer, as well as something of an entomologist, plant expert, veterinarian, soil specialist, or whatever else the occasion demands. He must know a lot of practical things about construction, drainage, soil dynamics, and machines. While he pointed out that a farmer must know how to take a machine apart, put it together, and make it work, he emphasized that the farmer must depend pri-

marily upon the agricultural engineer for this information and for development of the techniques, practices, and machines to enable him to increase his efficiency and the effectiveness of his operations.

In another general session address, "Research for Tomorrow's Agriculture," Dr. Robert W. Trullinger, chief, Office of Experiment Stations, U. S. Department of Agriculture, brought out the challenging need for redoubled effort on the part of agricultural engineers and other scientists to solve some of the present-day pressing problems of agriculture, if this basic industry and backbone of our nation is to progress and remain strong and prosperous.

Russell I. Thackery, executive secretary, Association of Land-Grant Colleges and Universities, delivered an interesting address on the National Science Foundation. He described the purpose, aims, and activities of the Foundation and pointed to its creation by recent legislation as a great national achievement.

At the luncheon on June 20, Dean Rusk, assistant secretary of state in charge of far eastern affairs U. S. State Department, gave an informal, but very informative talk on "An American Look at the International Situation." He stressed the unbelievable complexity and number of problems facing our present government and continuously demanding solution. He impressed upon his audience the great need of the United States for maturity in its outlook and in handling the problems of other nations; while the United States is a young nation, it is passing through an exceedingly difficult time. He said the type of maturity we must have is not obtained by virtue of age, but is dependent upon wisdom and a great understanding of the conditions and forces affecting all peoples.

Many favorable comments were heard about the programs offered by the various A.S.A.E. divisions but space limitations do not permit more adequate reporting here. A majority of the papers on these programs will be printed in AGRICULTURAL ENGINEERING or otherwise made available within the next few months. The interest value of the subject material covered was high and the effectiveness of the presentations was believed better than usual.

The Hotel Statler is to be commended for its fine accommodations and for their unusually good cooperation in assisting those responsible for local arrangements. They were quick to comply with any request, and their courteous efficient service was noticeable in the serving of the several banquets and luncheons and in the preparation of the meeting rooms.

About 400 A.S.A.E. members and their guests attended the Society's annual dinner and dance. S. P. Lyle proved an able toastmaster, indicating that the extension service is a good way to get around and to learn the techniques of savoir-faire. Honors and awards presented or cited by President Frank J. Zink following the dinner included the John Deere Gold Medal to Roy B. Gray, head, division of farm machinery (BPISAE), USDA; the Cyrus Hall McCormick Gold Medal to Arnold P. Yerkes, of Winnetka, Illinois, recently retired from the International Harvester Company where he was in charge of farm practice research; the ASAE Paper Awards to Wayne H. Worthington, Leonard J. Fletcher, L. L. Sammet, H. J. Barre, Robert A. Kepner, and Stephen J. Mech; the ASAE Collegiate Awards to W. R. Bender, North Carolina State College, and B. A. Jones, University of Illinois, in the undergraduate division, and A. C. Dale, Iowa State College, and M. L. Burgener, University of Illinois, in the graduate division; the Farm Equipment Institute Award to the ASAE student branch at the University of Nebraska, and a life membership in the Society to Fred L. Warner.

Following the presentation of the awards, retiring President Zink formally turned over the duties, honors, and official gavel to incoming President Fred C. Fenton. As his first official act, President Fenton honored Mr. Zink by bestowing on him the past-president's pin, the recognition symbol of the Society's esteemed group of past-presidents.

The entertainment for the annual dinner was of exceptionally high caliber, as was shown by the large number of encores which the audience requested. The Society members are deeply indebted to the Washington Section for procuring it, and to those industries and organizations whose generous donations made that feature possible.

The local trips to the National Bureau of Standards, the Naval Research Laboratory exhibit, the University of Maryland Wind Tunnel, and the USDA Research Center at Beltsville were well attended and well liked. The exhibits and demonstrations at the meeting measured up to high standards, but probably the one that attracted the most persistent crowd and which made most of the engineers wish they were small boys, so that they could manipulate the controls, was Libby-Owens-Ford solarometer. It was operated by D. C. Sprague, now a consultant to Libby-Owens-Ford, and his associates who demonstrated sun angles at any latitudes at different times of the day and seasons of the year, so that agricultural engineers can plan required window shading for optimum comfort and economics.

The work of the Society's Committee on Extension was very much in evidence and provided a large variety of displays to interest the meeting attendees between sessions. A large quantity of slides entered in the better visual-aids section were on display in a continuous viewing case. The outstanding entries in the master movie contest were shown to interested agricultural engineers on Tuesday evening. Attractive displays of the winning best bulletins and classroom manuals, safety exhibits, new agricultural engineering textbooks and demonstrations and models were also seen in the hotel corridors at the meeting.

In conformance with the opinions expressed by student delegates at the previous annual meeting, the National Council of ASAE Student Branches and the Committee on Student Branches provided a brief program for students so that they would have more time to attend the technical sessions of the regular meetings and to make professional contacts. The paramount feature of the student program was the annual complimentary dinner for members and faculty advisors of Student Branches of ASAE through the courtesy of the International Harvester Company. Dan M. Guy delivered an inspiring talk on the applications of agricultural engineering training. President Zink and President elect Fenton also spoke briefly to the group. Other features of the student program included announcements of the winner of the FEI Award and a specific discussion of reports entered in the competition; reports from the Student Branches; two personnel meetings with prospective employers to consider employment opportunities; discussion of the proposed ASAE Student Honor Award, and election of new officers for the National Council of ASAE Student Branches.

Under the sponsorship of the ASAE Committee on Irrigation M. R. Lewis, chairman, a very interested group of irrigation engineers, research engineers, and representatives of sprinkler irrigation equipment manufacturers met to discuss informally some of the problems and needs of sprinkler irrigation. While no definite action was taken by the group, a great deal of valuable information was exchanged and many viewpoints were aired on pertinent problems. Plans were made to hold a second irrigation conference at the next ASAE Winter Meeting in Chicago.

ASAE Paper Award Winners Named

BEST papers published in AGRICULTURAL ENGINEERING during 1949 were announced during the Society's annual meeting at Washington, D. C., last month.

The five winners, in the order of placing determined by the judges, were "Evaluation of Factors Affecting the Operating Stability of Wheel Tractors," by Wayne H. Worthington (March and April); "Adventures in Understanding — the Engineer as a Citizen," by L. J. Fletcher (September); "Air Flow in Poultry House Ventilation — A Theoretical Analysis," by L. L. Sammet and H. J. Barre (July); "A Continuous Spray-Type Seed Treater," by R. A. Kepner and L. D. Leach (November); and "Effect of Slope and Length of Run on Erosion Under Irrigation," by Stephen J. Mech (August).

Honorable mention was given to five additional papers as follows: "The Thermocouple in Agricultural Research," by Coby Lorenzen, Jr. (June); "Some Results of Milking Parlor Research," by J. W. Wilkins (December); "Equipment and Procedures for Farm Tractor Tire Studies Under Controlled Conditions," by I. F. Reed and M. O. Berry (February); "Cushion Hitch Developments," by A. W. Clyde (April) and "Possible Applications of Torque Converters in Farm Machines," by C. E. Frudden (September).

Members of the ASAE Committee on Paper Awards, which made the selections, were W. D. Hemker (chairman), P. W. Manson, J. L. Strahan, C. B. Richey, L. H. Skromme, and D. D. Smith.

Michigan Section Spring Meeting

A TRIP through the Great Lakes Steel Corporation mill at Ecorse, Detroit, was the opening feature of the meeting Saturday, June 3, of the Michigan Area Section of the American Society of Agricultural Engineers.

Approximately 60 members and guests of the Section went on the conducted tour in which they followed the steel-making process from the Bessemer and open-hearth converters through ingot casting, hot and cold rolling and cutting.

From the main plant the group went to the Michigan Steel Division plant for a showing of products of the company's Stran-Steel Division. These included a minimum steel quonset design and an inverted U-shaped air duct framework of channel and expanded sheet steel.

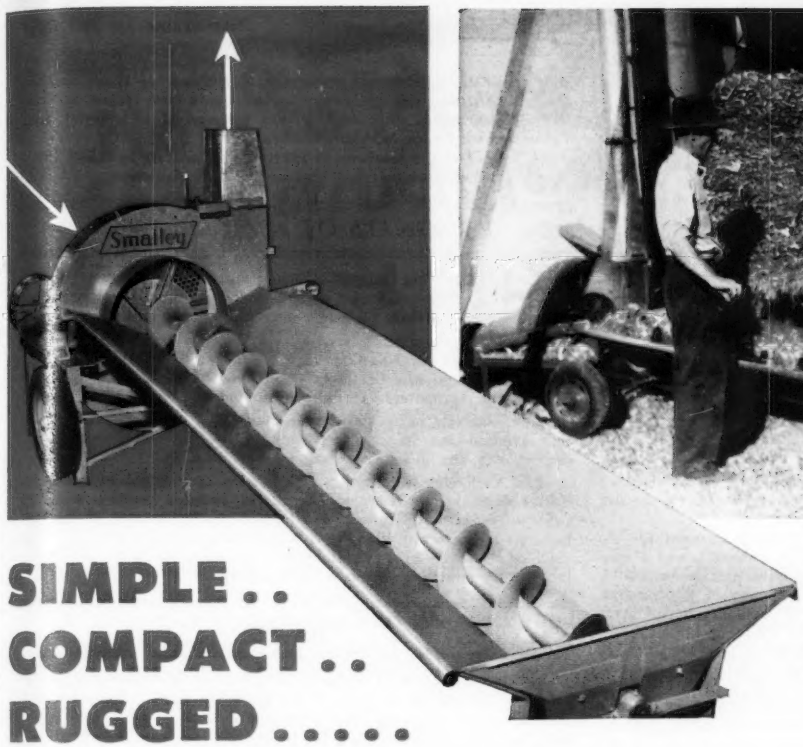
Some experimental steel foundation units for Stran-Steel buildings were also shown and the experiment explained.

Following the plant tour the group went to the Detroit Edison Company for lunch and an afternoon program.

W. J. Ridout, Jr., rural service manager, Edison Electric Institute, reported on farm electrification research by electric operating companies. In doing so he pointed out that the research is generally carried out by and as a result of cooperation between the companies and the agricultural engineering departments of colleges, experiment stations and other research agencies.

In presenting the subject of pen barn arrangement and management, B. F. Cargill, research instructor of agricultural engineering, showed how a number of layout and management factors influence labor, feed, and structural economy, and sanitation in pen barn operations.

W. H. Lowry, farm practice research division, International Harvester Company, reviewed progress in the *(Continued on page 358)*



Nine feet long, nine inches in diameter, this Link-Belt screw conveyor in the Smalley Forage Blower, is a one-piece, simple, and efficient means of feeding material into the fan.

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COMPACT..
RUGGED.....

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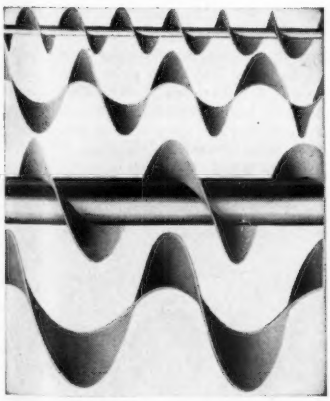

These views suggest the wide variety of diameters, pitches and gauges of screw conveyor, in continuous and sectional flight types, as manufactured by Link-Belt. For incorporating in agricultural implements, flighting can be supplied mounted or unmounted.

A positive feed, the simplest construction and practically no wear, attention or upkeep—these advantages make Link-Belt Screw Conveyor the most satisfactory choice of a feeding device on numerous agricultural implements. "Helicoid" (continuous) flighting, welded to pipe, forms a complete conveying mechanism in one piece. In operation the entire unit is active, there is no idle return.

Screw conveyors operate efficiently at any angle, from horizontal to vertical.

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LINK-BELT SCREW CONVEYOR

COLLARS · COUPLINGS · HANGERS · TROUGHS · BOX ENDS · FLANGES · THRUSTS · DRIVES

NEWS SECTION *(Continued from page 356)*

study of trace elements in soils. He pointed out that in addition to the trace elements showing important influence on crop production, small quantities of still other elements are important in soils and crops as a means of satisfying nutritional needs of livestock and human beings.

In the absence of J. C. Cahill, chairman of the Section, J. S. Boyd, vice-chairman, presided at the meeting. He reported that as a result of the recent mail ballot, Section officers elected for the new year were as follows: Chairman, David B. Poor; vice-chairmen, Robert E. Johnson, Q. J. McDowell, and Joseph Patterson; secretary, Paul E. Schleusener; and nominating committee, H. J. Gallagher, Dan M. Guy, and Howard F. McColly.

The meeting adjourned to meet again next fall on a suitable date, probably in November.

Pacific Northwest Section to Meet at Yakima

OCTOBER 19 and 20, 1950, are the dates of the next yearly meeting of the Pacific Northwest Section of the American Society of Agricultural Engineers to be held at Yakima, Washington, with headquarters at the Commercial Hotel. Registration will begin on the evening of Wednesday, October 18, and field trips have been scheduled for the day following the meeting, Saturday, October 21.

The general theme of the program that is being arranged for the various meeting sessions this year will be "Reclamation", and a substantial part of the program is already complete. All members of ASAE residing in the Section area, which includes the states of Washington, Oregon, and Idaho and the provinces of British Columbia and Alberta are urged to make a special effort to attend the meeting.

A cordial invitation is extended also to members of the Society residing in other parts of the country who care to attend the meeting. ASAE members non-resident of the Section area who plan to attend are requested to write to the Section Secretary, Frank G. Mackaness, Electric Building, 621 S. W. Alder St., Portland 5, Ore., who will in turn be glad to send them copies of the program of the meeting and tour and travel information.

Roth New Chairman Iowa-Illinois Section

ROBERT R. ROTH, junior design engineer, Minneapolis-Moline Co., was elected the new chairman of the Iowa-Illinois Section of the American Society of Agricultural Engineers at the last meeting of the Section's 1949-50 meeting season, held at Rock Island, Illinois, May 27. He succeeds Robert H. Meier, product engineering department, Deere and Company.

The two new vice-presidents of the Section elected at the meeting are Jay G. Porterfield, a member of the agricultural engineering department, Iowa State College, and Carl Widseth, manager, steel building and farm equipment division, Miller-Piehl Equipment Co., Davenport, Iowa. The new secretary of the Section is D. O. H. Miller, design engineer, John Deere Harvester Works, East Moline, Ill.

The technical portion of the program of the meeting included a paper on the evaluation of nodular iron for farm machinery by H. Bornstein, head of the materials engineering department of Deere and Co., and a discussion of electric power application to farm chores, by D. G. Womeldorff, agricultural engineer and manager of agricultural sales, Public Service Co. of Northern Illinois.

A feature of the luncheon at noon was an address by ASAE President F. J. Zink, and president of Frank J. Zink Associates.

PERSONALS OF ASAE MEMBERS

Paul C. Baker has resigned as managing editor of "Farm Implement News" to accept appointment as advertising representative and special feature writer of "Farm Journal", with headquarters at Chicago.

Robert S. Calkins recently resigned as executive secretary of the National Association of Soil Conservation Districts to accept appointment as zone conservationist (engineer), Soil Conservation Service, U. S. Department of Agriculture. He will be located at Upper Darby, Pa.

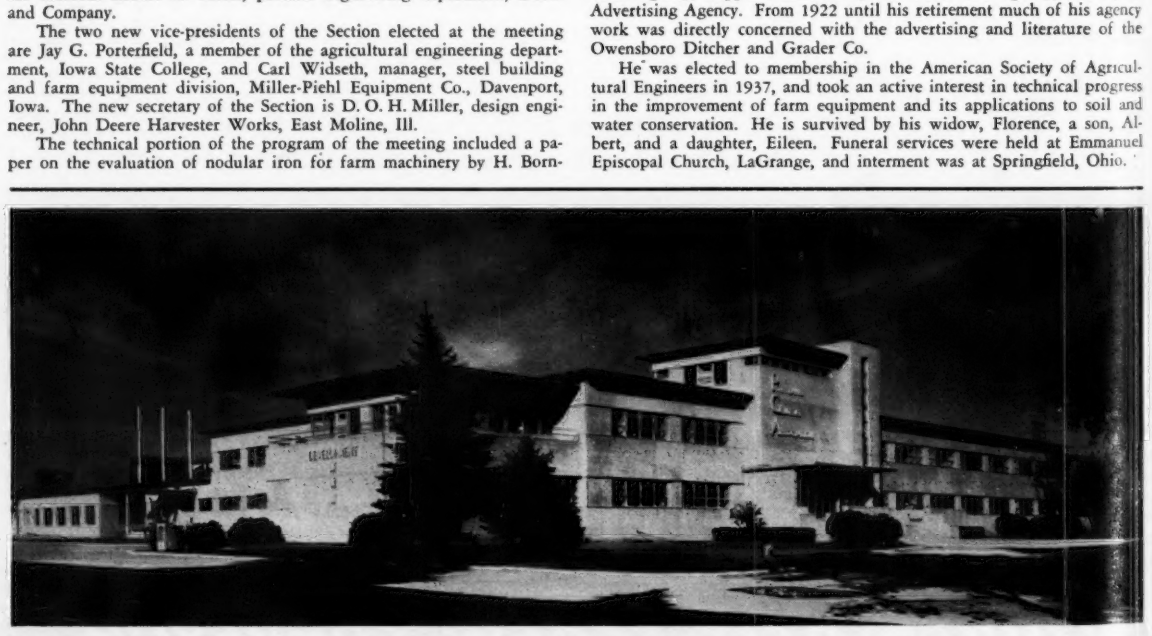
Donald E. Kuska has resigned as engineering designer, North American Aviation, Inc., to accept a position as design engineer on farm machinery with The Oliver Corporation, South Bend, Ind.

Earl K. Rambo is resigning as extension agricultural engineer, Arkansas Agricultural Extension Service, to accept a position with the Office of Foreign Agricultural Relations, U. S. Department of Agriculture. At the outset of taking up his new employment, he will be acting chief of the U. S. Agricultural Mission to India, where he will be located at the American Embassy in New Delhi.

Necrology

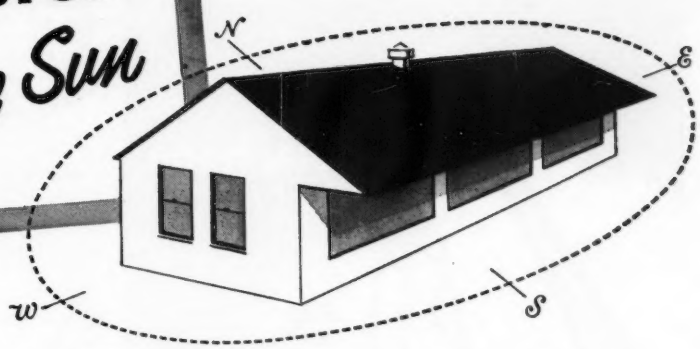
GEORGE H. DAUGHERTY passed away June 4 at MacNeal Memorial Hospital, Berwyn, Illinois. He was nearly 78 years of age and had retired in January of this year from active work as account executive with Symonds, MacKenzie and Co. A native of Clermont County, Ohio, he started his career as a newspaper reporter at Springfield, Ohio, and progressed to managing editor and editor of several Ohio and Indiana papers in succession. In 1906 he entered the advertising field as a copywriter for the Critchfield Advertising Agency in Chicago. In this capacity he wrote advertising for the International Harvester Company and established a lifelong interest in the farm equipment field. He was also associated at various times and in various advertising capacities with the Lord and Thomas Agency, Michigan Motor Car Co., Johnson-Read Agency, Capper Publications, Porter-Eastman Agency, and Byrne Advertising Agency. From 1922 until his retirement much of his agency work was directly concerned with the advertising and literature of the Owensboro Ditcher and Grader Co.

He was elected to membership in the American Society of Agricultural Engineers in 1937, and took an active interest in technical progress in the improvement of farm equipment and its applications to soil and water conservation. He is survived by his widow, Florence, a son, Albert, and a daughter, Eileen. Funeral services were held at Emmanuel Episcopal Church, LaGrange, and interment was at Springfield, Ohio.



This picture shows the new research and development laboratories of the Portland Cement Association which were dedicated at Skokie, Ill., on June 8. They are the largest and most completely equipped laboratories in the world, devoted exclusively to research on cement and concrete. There are two architectural buildings with the total floor space of 98,000 square feet. The main building houses the offices and laboratories of the various research and development sections and their related temperature, humidity, chemical and physical testing rooms. The auxiliary building provides space for storage and processing operations. There are more than 30 specialized laboratories, testing and curing rooms in the two buildings. In some of these spaces conditions of arctic cold, desert dryness and tropic heat are duplicated with temperatures ranging from 20 degrees below zero to 130 degrees Fahrenheit. Equipment of the laboratories ranges from the very delicate and highly complex, to powerful testing machines, one of which is capable of exerting one million pounds of pressure on concrete specimens. The apparatus and facilities provided in these laboratories are the finest and most modern obtainable for research on cement and concrete

How to locate farm structures for *Best Use of the Sun*



By proper building location and window treatment you can provide better year-round environment to help keep livestock and poultry more healthful and more productive. In summer . . . cooler, well-daylighted buildings. In winter . . . drier interiors, better sanitation and greater warmth.

The provision of adequate daylight calls for large windows properly located and insulated with *Thermopane**. This double-glass unit traps sun heat or animal heat inside the building, thereby protecting the animals from sudden temperature changes and providing a generally improved environment for them.

Solar design also calls for methods of control, you want to bring in winter sun . . . you don't want summer sun, except in early morning or before cool evenings. The diagrams and paragraphs below serve as limited guides for building orientation for sun control.

SOME TYPES OF SHADING

OVERHANG — can be a roof extension, a separately-built unit, or awnings. Angle of the device should be calculated according to sun positions.

FOLIAGE — vines, shrubs and deciduous trees are excellent shading devices, but let winter sun through.

SIDE VANES — for some east and west exposures, side vanes, either solid or vine-covered, may be used.

WHY THERMOPANE INSULATING GLASS MAKES SOLAR HEATING PRACTICAL

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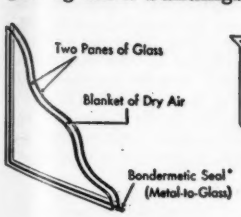

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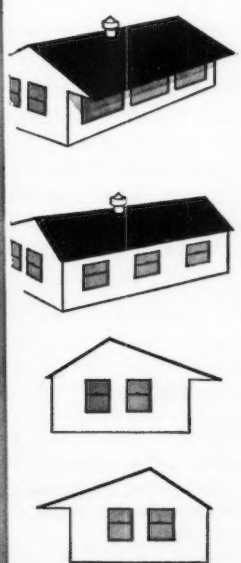


SOUTH — for maximum solar heat input in winter provide a large window area facing south. An important element is the extended roof or other overhang. It lets in the low winter sun, but can completely shade windows from high, hot summer sun. With proper data on window height, building height and latitude it is possible to compute the right amount of overhang. On request, we can assist you in this.

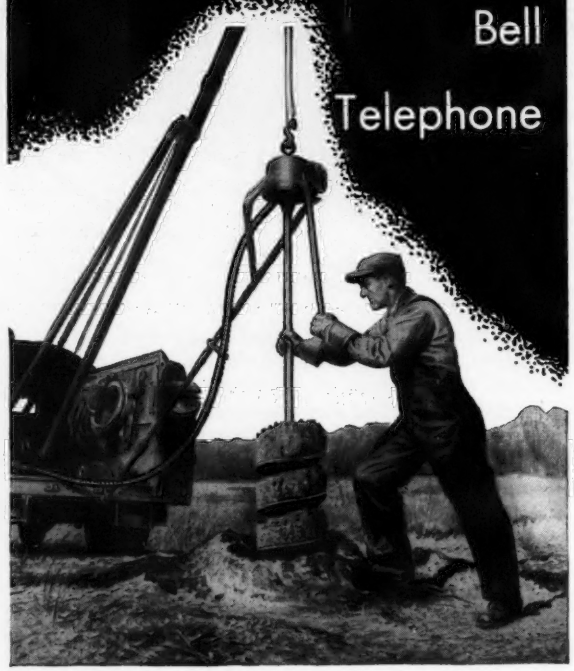
NORTH — use these windows for ventilation and to bring in north daylight. No overhang is recommended.

WEST — shade should be provided to keep out afternoon summer sun. Shrubs or trees are effective—their lack of foliage in winter permits late sun to warm the interior before the cool night sets in.

EAST — windows admit daylight to make the interior brighter and cheerier. An overhang can be used to keep out high morning sun in summer.

STOW case history #1

STOW flexible shaft on the job for Bell Telephone



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NEWS SECTION

(Continued from page 358)

McKibben to Head Tillage Machinery Lab

THE U. S. Department of Agriculture has announced the appointment of Dr. E. G. McKibben as engineer in charge of investigations on tillage and related problems at the U. S. Tillage Machinery Laboratory at Auburn, Ala. With this appointment, research at the laboratory in the mechanics of soil dynamics, tillage methods and machines, tire traction, soil compaction or other effects of machines on soil structure and resulting yields of crops will be intensified. A division of the work at the laboratory is being made to give added emphasis on the engineering problems in production and harvesting of oil nut crops, including both peanuts and tung nuts. I. F. Reed, head engineer at the laboratory for the last several years, will be in direct charge of the work on oil crop equipment.

Dr. McKibben goes to the Tillage Machinery Laboratory from the Pineapple Research Institue in Honolulu, where he has been head of the agricultural engineering department for several years. A graduate of Iowa State College in agricultural engineering, he did advanced work at University of California and later returned to his alma mater at Ames as associate professor in agricultural engineering for 14 years during which he earned his PhD degree. During his graduate studies Dr. McKibben gave special attention to soils and soil physics. He is an international authority on tillage mechanics and has served in a consulting capacity with both the Department of Agriculture and the Armed Services.

Prior to going to the Hawaiian Islands, Dr. McKibben was head of the department of agricultural engineering at Michigan State College. In 1940 one of his professional reports was designated as the top Paper Award. In 1949, he was chosen to receive the Cyrus Hall McCormick gold medal for exceptional and meritorious engineering achievement in agriculture. He is the co-author of two textbooks, one on farm machines published last year, and the other on farm power, the latter now in manuscript form.

PSAE Organized

THE above initials stand for "Philippine Society of Agricultural Engineers" which has just been organized by two ASAE members Felix D. Maramba, director of plant industry and assistant managing director, Rice and Corn Production Administration and Dr. Santiago R. Cruz, head of the agricultural engineering division in the Philippines Department of Agriculture and Natural Resources, and others actively engaged in agricultural engineering work in the Philippines. The new Society is patterned after ASAE, and its officers include Mr. Maramba as president and Dr. Cruz as editor of the new society's journal.

Engineers Participate in Tobacco Workers Conference

AGRICULTURAL Engineers formed an engineering section of the Tobacco Workers Conference at the University of Florida, Gainesville, June 6 to 9, to team up with agronomists, pathologists, and entomologists. The agricultural engineering staff of the University of Florida was host for the first meeting. G. W. Giles, head, agricultural engineering department, North Carolina State College, acted as chairman, and V. H. Baker, associate agricultural engineer, Virginia Polytechnic Institute, was secretary.

In attendance were 24 agricultural engineers from industry, state institutions, and the U. S. Department of Agriculture. The purpose of the meeting was to find out what the various engineers are doing in tobacco production, harvesting, and curing, and also to determine the need for proposed research projects in the various states. Dr. O. A. Brown, USDA, led a one-half day conference devoted to curing, grading, and marketing, and J. L. Shepherd of Georgia led a half-day program on the mechanization of production and harvesting. A joint session with the agronomists on physiology and biochemistry provided two interesting talks, one on the comparative analysis of tobacco cured in the presence and absence of combustion gases, and the other on the effects on composition of flue-cured tobacco leaf produced by varying or changing curing conditions.

A one-day field trip included a visit to the Florida Experiment Station tobacco irrigation plots and a transplanting machine demonstration conducted by five different manufacturers of transplanting equipment. The Griffin Brothers farm was also visited and there the group observed three very ingenious machines for cultivating tobacco. The most interesting was a "riding hoe" which actually hoed between the plants and along-side the plants as the machine moved through the field. The Griffin Brothers have also built a very effective machine for fumigating the soil for the control of nematodes. Experiments being conducted on fertilizer and insecticide replacements in corn, peanuts, and tobacco were also observed.

A business session was held and officers elected for the coming year. J. L. Shepherd, agricultural engineer, *(Continued on page 362)*

No More "Blindfold" Tractor Operation

PROOF-METER

STANDARD ON EVERY NEW FORD TRACTOR

The Proof-Meter is actually 5 instruments in 1. At a glance it tells engine speed in r.p.m.'s; tractor travel speeds in miles-per-hour in any gear; power take-off speed; belt pulley speed; and it tells the number of hours of operation based on an average engine speed of 1580 r.p.m.

Dearborn FARM EQUIPMENT

Ford TRACTOR

For many years almost all aspects of farming have become increasingly scientific. Until the middle of 1950 the operation of a tractor—one of the principal jobs of modern farming—was largely based on guesswork as it had been for decades. Tractor travel speeds, engine speeds, P.T.O. speeds and belt pulley speeds generally were determined by "feel," and "how she sounds." These yardsticks can hardly be described as scientific criteria.

Today, the need for such guesswork is gone! A remarkable new instrument, the Proof-Meter (standard equipment on every new Ford Tractor) permits farmers to get top performance and economy *at all times.* Moreover these benefits extend to the implements the Ford Tractor powers and to the jobs they do!

For instance, let's consider the application of chemical weed killers such as 2, 4-D. The recommended application depends on nozzle size, pump pressure and *travel speed.* With the Proof-Meter the farmer can hit and hold the tractor travel speed. He can be assured of applying enough chemical to kill the weeds and he can avoid overdoses that might injure the crop.

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NEWS SECTION

(Continued from page 360)

Georgia Coastal Plains Experiment Station, was elected as chairman and R. W. Wilson, agricultural engineering department, North Carolina State College, was elected secretary. The next meeting will be held at Clemson Agricultural College in November, 1951.

At the business session a number of resolutions were passed including one which stipulated that future programs would consist mainly of progress reports of work with a portion of the program devoted to plans for future work and research programs. Another resolution adopted proclaimed that the time is ripe for the Engineering Section of the Conference to begin work on a uniform set of curing recommendations for bright leaf and burley growers on a regional basis. Recommendations prepared by committees will be presented at a subsequent meeting for consideration of the Engineering Section.

New ASA Plow Bolt Standard

A NEW American Standard "Plow Bolts, ASA B 18-9-1950" approved in March by the American Standards Association, has recently been published by the American Society of Mechanical Engineers, one of the joint sponsors. The Society of Automotive Engineers was also a joint sponsor of the new Standard.

A. W. Lavers, president, Lavers Engineering Co., officially represented the American Society of Agricultural Engineers on Subcommittee 6 of ASA Sectional Committee B18 which developed the standard.

The new standard supersedes Standard B 18f-1928. It specifies the standard dimensions for No. 3 and No. 7 regular and repair head, and No. 4 and No. 6 repair head bolts. Dimensions of No. 4 and No. 6 regular head bolts are included in an appendix as supplementary information, with a recommendation that preference be given to No. 3 or No. 7 in new designs.

In recommending this standard the committee favored the types and sizes in most common use, and recognized the increasing use of medium carbon and alloy steels in plow bolts, as well as the growing use of plow bolts in railroad equipment, deep soil plows, cleaning machinery, tractors, corn cutters, manure spreaders, hay rakes, and other implements of widely varied types.

Applicants for Membership

The following is a list of recent applicants for membership in the American Society of Agricultural Engineers. Members of the Society are urged to send information relative to applicants for consideration of the Council prior to election.

Ashley, Walter M.—Student, University of Illinois. (Mail) 8321 Dante Ave., Chicago 19, Ill.

Baba, Telischi—Graduate student, agricultural engineering dept., Iowa State College, Ames, Iowa

Bailey, William A.—Student, University of Nebraska. (Mail) 76 Centre St., Dorchester, Mass.

Barnason, Duane E.—Student, University of Nebraska. (Mail) Red Cloud, Nebr.

Barrows, Charles S., Jr.—Student, Virginia Polytechnic Institute. (Mail) 122 Chelmsford Rd., Rochester 18, N. Y.

Bell, David K.—Parts and service dept., Jackson & Preston Equipment Co., Dublin, Va.

Butler, James L.—(Mail) R. R. 5, Sevierville, Tenn.

Butler, Robert E.—Student, University of Nebraska. (Mail) 427 East 5th St., Claremore, Okla.

Brinegar, Robert W.—(Mail) P. O. Box 481, State College, N. M.

Brookfield, Myron B.—Assistant agricultural engineer (research), Farm Electrification Council, Cornell University, Ithaca, N. Y.

Butts, M. K.—General sales manager, Eureka Mower Co. (Mail) 66 Merritt Pl., New Hartford, N. Y.

Cerny, Daryl D.—Electrical advisor, Cherry-Todd Electric Cooperative, Inc., Valentine, Nebr. (Mail) c/o Rural Electrification Administration, USDA

Curley, Robert G.—Student, University of Nebraska. (Mail) Craig, Nebr.

Curry, Donald B.—Junior engineer, Farmers Home Administration. (Mail) 333 S. Grant St., Casper, Wyo.

Evans, Robert H.—District sales manager, Great Lakes Steel Corp., Stran-Steel Div., (Mail) 268 Friendship Rd., Drexel Hill, Pa.

Foster, Edwin T.—Rural service advisor, Consumers Power Co. (Mail) R. R. 3, Benton Harbor, Mich.

Foyston, Donald E.—Salesman, Massey-Harris Co., Ltd. (Mail) R. R. 4, London, Ont., Canada

Hagen, Clifford G.—Farm training instructor. (Mail) East Grand Forks, Minn.

(Continued on page 364)

NOW... NEW IDEA

REAR LOADING two-row corn picker offers advantages corn farmers want

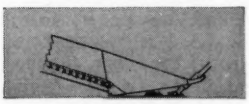
These three points are REAL SELLING POINTS!

Inner-seal plug
Bronze bushing
Case-hardened stud
Malleable bracket

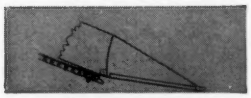
Here's another reason why NEW IDEA pickers are the "pick o' the pickers"

A renewable bronze bushing, pressed into the lower end of the snapping roll, turns on a case hardened steel stud, keyed and riveted on a drop forged bracket. An inner seal provides a dust-proof bearing, well protected by positive lubrication.

1. Note high position of ordinary gathering chains



2. Ordinary points are thrown out of position by obstacles.



3. Note low position of NEW IDEA gathering chains.

4. NEW IDEA points follow contour of ground closely

The competent engineering and sound construction that comes only from experience is behind every NEW IDEA machine. That's why American Agriculture looks to NEW IDEA for the highest quality farm machinery, and that's why the NEW IDEA Two-Row Corn Picker now offers more real value than ever before.

All the time-tested features that have made NEW IDEA the most popular picker in the corn belt have been included. It harvests corn faster with less help, and gets more bushels per acre than any other machine or method. Now, with a rear loading elevator and wagon hitch in line with the tractor, there are extra advantages. The unit is more flexible — fields are opened more easily and with less down rows — less space is required to operate.

Here is a machine that you can recommend with confidence to anyone who wants greater efficiency and economy in corn harvesting. You'll want to know more about the outstanding features of this new picker, so see your local NEW IDEA Dealer or write for more information today.

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DIVISION AVCO MANUFACTURING CORPORATION
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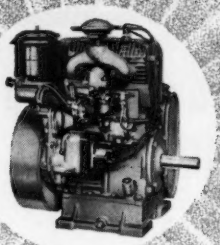
FOR YOUR 7 TO 13 H.P. POWER JOBS
Two-Cylinder
WISCONSIN
Heavy-Duty
Air-Cooled
ENGINES



Models TE and TF standard engine illustrated; also available as complete Power Units with Clutch Take-Off Assembly or with Clutch Reduction Assembly.

Designed and built to traditional Wisconsin Motor heavy-duty service standards, Models TE-TF Air-Cooled 2-cylinder engines provide ideal power either as component units on original equipment, or as stationary or portable general purpose power within the 7 to 13 hp. bracket.

The Model TE delivers from 7.2 to 11.2 hp. and the Model TF turns up 8.6 to 13.3 hp. within a 1400 R.P.M. to 2600 R.P.M. speed range. Features include: tapered roller bearings at BOTH ends of the heat-treated, drop-forged crankshaft; high tension rotary-type OUTSIDE Magneto with impulse coupling; oil bath air cleaner; ¾" standard float feed carburetor; positive lubrication by Pump with individual oil stream to each rod . . . plus dependable air-cooling at all temperatures from sub-zero to 140°F.

For "Most H.P. Hours" of on-the-job power service, specify Wisconsin Air-Cooled Engines . . . single cylinder, 2-cylinder and 4-cylinder, in a complete power range from 3 to 30 hp.

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Applicants for Membership

(Continued from page 362)

Hansen, E. Deane—Farm machinery maintenance, William Gehring, Inc., Rensselaer, Ind.

Henkin, Ezra N.—(Mail) 2525 Minnesota Ave., S.E. No. 7, Washington 20, D. C.

Herr, John H.—Student, Pennsylvania State College. (Mail) Landisville, Pa.

Hodgell, Murlin R.—Extension architect, Kansas State College, Manhattan, Kans.

Hummel, Gene M.—Engineer, farm electrical dept., United Cooperatives, Inc., 243 E. Main St., Alliance, Ohio

Irish, Wilmot W.—Sales trainee, Louden Machinery Co., Fairfield, Iowa. (Mail) 301 S. Court St.

Jain, B. K. Singh—(Mail) 744, Churi Wali Gali, Naya Ganj, P.O. Hathras City, Dist. Aligash, U. P. India

Johnson, Glen L.—Trainee, Deere & Webber Co. (Mail) Gregory, S. D.

Keppy, M. D.—Service manager, Ford Motor Co. of India, Ltd., Post Box 499, Swadeshi Mills Compound, Bombay, India

Lamb, Lawrence C.—Graduate student, agricultural engineering dept., New York State College of Agriculture, Ithaca, N. Y.

Luttrell, Dan H.—Student, University of Tennessee. (Mail) R. R. 1, Corryton, Tenn.

Markwardt, Stanley L.—Agricultural instructor, veterans' training program, Rugby High School, Rugby, N. D.

McPhee, George E.—Extension agricultural engineer, University of Minnesota, University Farm, St. Paul 1, Minn.

Moore, Robert E.—(Mail) R. R. 3, Clarksville, Tex.

Morison, Howard E.—Manager, agricultural div., Crucible Steel Co. of America, 535 Smithfield St., Pittsburgh 22, Pa.

Morrison, Stanton R.—Student, University of Missouri. (Mail) 201 Defoe Hall, Columbia, Mo.

Myers, Earl A.—(Mail) R. R. 1, Thomasville, Pa.

Nelson, Laurance M.—Engineering trainee, John Deere Harvester Works. (Mail) 1930 Tremont Ave., Davenport, Iowa

Nelson, Robert E.—Student, University of Nebraska. (Mail) R. R. 1, Pilger, Nebr.

Nitshke, H. Allen—Agricultural engineer, product research and development div., Butles Mfg. Co. (Mail) 903 West Blvd., N., Columbia, Mo.

Norton, Richard L.—Student, Oklahoma A. & M. College. (Mail) R. R. 1, Blanchard, Okla.

Poehlmann, Alfred E.—Engineer, product application div., agricultural section, The Gates Rubber Co., 999 S. Broadway, Denver 17, Colo.

Ryberg, Berthol E.—Engineer, Massey-Harris Co. (Mail) Y.M.C.A., Racine, Wis.

Sawin, Henry W.—Student, Purdue University. (Mail) 1612 Draper St., Indianapolis, Ind.

Soutar, D. S.—Head, farm buildings dept., North of Scotland College of Agriculture, Craibstone, Bucksburn, Aberdeenshire, Scotland

Spencer, Loren J.—Agricultural engineer, Soil Conservation Service, USDA, Beaver, Utah

Stermer, Raymond A.—Agricultural engineer, Soil Conservation Service, USDA. (Mail) R. R. 3, Rosebud, Tex.

Thompson, Howard G.—(Mail) Osborn, Mo.

Toothman, James M.—(Mail) Box 133, Alderson, W. Va.

Van Aken, Fred D.—Student, Rutgers University. (Mail) S. Main Rd., Vineland, N. J.

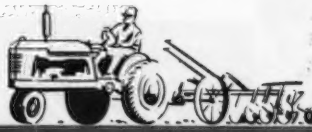
TRANSFERS OF MEMBERSHIP GRADE

Edminster, Talcott W.—Agricultural engineer, Soil Conservation Service (Research), USDA, Box 99, Blacksburg, Va. (Junior Member to Member)

McConnie, Paul L.—Plantation manager, Such. J. O. McConnie, Sagrado Corazon 458, Santurce, Puerto Rico (Junior Member to Member)

New Bulletins

Selected Bibliography on Agricultural Engineering and Related Topics (Canadian publications), by W. Kalbfleisch and Allan Magee. This is a 1950 revision of a previous issue, and has been compiled for The National Committee on Agricultural Engineering by the divisions of field husbandry, soils, and agricultural engineering, Central Experimental Farm (Ottawa). It lists primarily items on land development, farm machinery, and farm buildings and equipment, on 37 pages, 8x13 inches.



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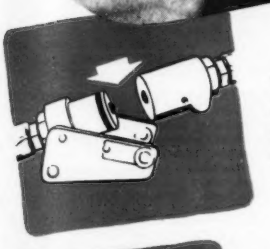
The first breakaway coupling which meets every requirement for farm tractor use

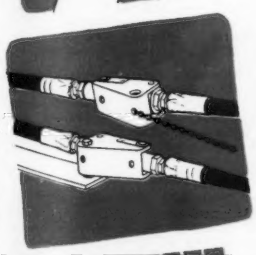


INSTANTLY CLEANED

When disconnected the female end telescopes flush with the face of the coupling. A quick wipe cleans both ends—there are NO holes or dirt traps.

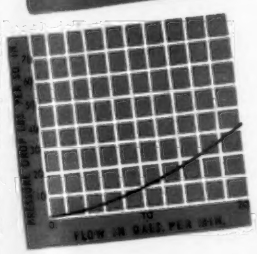
CONNECTS AND DISCONNECTS BY HAND

—even under full operating pressure of 1500 PSI. Absolutely no tools needed. Unlike ordinary couplings, Bendix LINE-LINKS incorporate an exclusive *pressure lock* which makes hand operation possible.



FLEXIBILITY OF MOUNTING

LINE-LINKS can be permanently bolted to tractor or implement. Or one can be bolted, the other chain connected. Or both can be chain connected.



LOWEST PRESSURE DROP

Due to their unique design LINE-LINKS have the *lowest pressure drop* of any coupling on the market.

The new Bendix LINE-LINK is the answer for a quick-acting hydraulic coupling which incorporates *every* desirable feature for convenience, flexibility and price!

LINE-LINKS are easy to clean because the two mating surfaces provide flush faces—there are NO holes or recesses. They are instantly connected and disconnected by hand, even under full pressure...and they will automatically break away. They are easy to install... and they are competitively priced.

For connecting drawn implements behind farm tractors, LINE-LINKS have proved their outstanding value in actual service over the past year. In addition, they are already being supplied as original factory equipment on a nationally known line of tractors.

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NORTH HOLLYWOOD, CALIF.

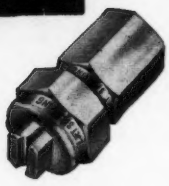
SPRAYING SYSTEMS

TeeJet

SPRAY NOZZLES

for

all AGRICULTURAL SPRAY OPERATIONS



TeeJet Spray Nozzles are precision made to provide uniform distribution . . . in all capacities on all spray rigs and portable sprayers. Orifice tips and strainers in all sizes for all operations . . . may be easily interchanged and spray direction quickly aligned by means of patented V-groove tip design. Write for information and ask for Bulletin 55.

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large area sprinklers for lightweight pipe for **Simplified Crop Irrigation**

Taking water from nearby lakes, streams or well for large area irrigation is easier and more efficient with Skinner large area sprinklers. Connected to lightweight pipe with flexible couplings you get uniform coverage up to slightly less than 3 acres . . . pan test curves are available. Skinner Sprinkler features include: adjustment for controlling rotation, working parts easily accessible, no tool required when making adjustments, bronze, brass and stainless steel parts throughout. Write today for circular No. 449 for your files.

Made in complete range from 1GPM and 5 lbs. pressure to 410 GPM and 100 lbs. pressure.

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SKINNER—Pioneer and Leader in Irrigation for nearly half a century.

Personnel Service Bulletin

The American Society of Agricultural Engineers conducts a Personnel Service at its headquarters office in St. Joseph, Michigan, as a clearing house (not a placement bureau) for putting agricultural engineers seeking employment or change of employment in touch with possible employers of their services, and vice versa. The service is rendered without charge, and information on how to use it will be furnished by the Society. The Society does not investigate or guarantee the representations made by parties listed. This bulletin contains the active listing of "Positions Open" and "Positions Wanted" on file at the Society's office, and information on each in the form of separate mimeographed sheets, may be had on request. "Agricultural Engineer" as used in these listings is not intended to imply any specific level of proficiency, or registration, or license as a professional engineer.

NOTE: In this Bulletin the following listings still current and previously reported are not repeated in detail; for further information see the issue of AGRICULTURAL ENGINEERING indicated:

POSITIONS OPEN: (1949): AUGUST—O-34-675. NOVEMBER—O-127-690. (1950): JANUARY—O-189-692. MARCH—O-262-700, 262-701. MAY—O-308-714, 329-715. JUNE—O-355-717, 379-718, 393-719, 395-720, 407-721.

POSITIONS WANTED: (1949): JULY—W-13-299. SEPTEMBER—W-67-312. OCTOBER—W-111-316. DECEMBER—W-145-323, 146-324, 137-327. (1950): JANUARY—W-164-331, 175-334, 179-335, 190-338. MARCH—W-227-351, 247-352, 228-353, 256-355, 257-359, 256-360, 268-361, 258-362. APRIL—W-294-368, 304-370, 291-373, 307-375. MAY—W-320-376, 327-377, 328-378, 333-380, 338-383, 339-384, 349-385, 351-386,. JUNE—W-348-391, 366-392, 364-393, 380-394, 384-395, 361-396, 383-397, 387-399, 274-400, 369-401, 378-402, 354-403, 394-404.

NEW POSITIONS OPEN

PROJECT ENGINEER and layout designer for design and development on established line of farm and garden tractors and implements. Location Wisconsin. BS deg in agricultural or mechanical engineering. Minimum of 5 years experience in product design and development in farm power or automotive equipment field. Must have proven supervisory and managing ability to coordinate the work of others and to plan and carry out development programs. Opportunity for advancement. Age 28-35. Salary open. O-360-722

EXTENSION AGRICULTURAL ENGINEER for work in fields of rural housing, farm buildings and equipment, farm machinery, and utilities in a western state. MS deg in agricultural engineering. Require extension or comparable field experience, with knowledge of principles of teaching and demonstration, and good public relations; tact, good judgment and common sense, a spirit of cooperation, and a liking for work with people. Advancement in salary customary. Opportunity for supervisory position. Age 28-45. Salary $5200-5400. O-396-723

ASSISTANT PROFESSOR of agricultural engineering for teaching and research in irrigation in a southwestern land grant university. MS deg in agricultural or civil engineering. Want man with some practical experience in irrigation and usual qualifications for college teaching and research. Permanent position. Normal opportunity for advancement. One month vacation. Age 30-35. Salary $4700 (approximate), 12-mo basis. O-418-724

INSTRUCTOR in agricultural engineering to teach farm power and machinery courses and conduct research in cotton mechanization. BS deg in agricultural engineering or equivalent with usual qualifications for college teaching and research, and some experience, both in teaching and in mechanized farming, preferably in cotton production. Temporary one-year appointment only. Future possibilities up to individual. Salary $3000-3600 range. O-418-725

GRADUATE RESEARCH ASSISTANT for half-time research in rural electrification and farm structures; half time on study toward an MS degree. BS deg in agricultural engineering, or equivalent. Usual personal qualifications for advanced study and research. May carry enough credits to earn master's degree in about four quarters. Opening effective at beginning of the next fall quarter. Salary $110 per mo. O-421-726

IRRIGATION SALES ENGINEER for dealer and farmer contacts, design and sales work on sprinkler irrigation systems in southern California and Arizona. BS deg in agricultural engineering. Reliable, sales personality. Expert knowledge of centrifugal pumps, engineering and farming practices. Opportunity for advancement unlimited. Age 30-35. Salary $275 mo plus commission, to start. O-425-727

NEW POSITIONS WANTED

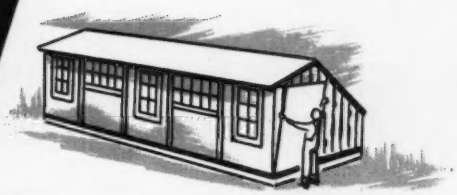
DESIGN, development, or research in power and machinery, with college, experiment station, or manufacturer, preferably in Midwest. BS deg, division of special services for war veterans, 1949; and BS deg in agricultural engineering, August 1950, University of Illinois. Farm background. Storekeeper for Central Illinois Public Service, 3½ mo. Half-time assistant in agricultural engineering, one semester. War enlisted and commissioned service in Army Air Force, over 3 yr. Married. Age 25. No disability. Available Sept. 1. Salary $3000. W-399-40

SALES, service, writing, instruction on new equipment, or sales trainee program organizer and instructor in power and machinery, with manufacturer or distributor, anywhere in USA. BS deg in agriculture, major in agricultural engineering, 1950, University of Wisconsin. Farm background. Sales with eastern circulation company, one year. Sales with home insulation company, 3 mo. Machinist helper in factory, 18 mo. War service in Navy 3 yr. Married. Age 27. No disability. Available now. Salary open. W-400-406

DESIGN, development, research, service, or promotion in power and machinery, farm structures, or soil and water field, in federal agency or private industry, anywhere in USA. BS deg in agricultural engineering, 1950, Purdue University. Special training in commercial illustrating. Modern Midwest farm background. Summer work experience with aluminum company as mill helper in extension department, and as trucker for manufacturer of machine parts. Single. Age 21. No disability. Available now. Salary $3100. W-402-407

(Continued on page 368)

QUICK QUIZ!



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1. Resist weather
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4. Easily disinfected
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6. Dense
7. Smooth
8. Grainless
9. Great structural strength
10. Uniform structure
11. Dimensionally stable
12. Equal strength in two directions
13. Won't split
14. Won't crack
15. Won't chip
16. Won't dent
17. Won't splinter
18. Won't rust
19. Won't corrode
20. Won't absorb odors
21. Can be sawed
22. Can be nailed or screwed
23. Can be bent
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RATES: Announcements under the heading "Professional Directory" in AGRICULTURAL ENGINEERING will be inserted at the flat rate of $1.00 per line per issue; 50 cents per line to A.S.A.E. members. Minimum charge, four-line basis. Uniform style setup. Copy must be received by first of month of publication.

PERSONNEL SERVICE BULLETIN

(Continued from page 366)

DESIGN, service, or management in power and machinery or farm structures, with manufacturer or distributor anywhere in USA. Willing to travel part time. BS deg in agriculture, 1950, University of Florida. Farm background. Part time work with general contractor, one year. War service in Navy over 3 yr, and including 3 yr as aviation mechanic. Married. Age 26. No disability. Available now. Salary open. W-382-408

DEVELOPMENT, research, or management in soil and water field, in public service or private industry, preferably in Southeast. BS deg in agricultural engineering, 1949, North Carolina State College. MS deg in agricultural engineering expected in fall, 1950, Virginia Polytechnic Institute. Farm background. War enlisted service 3 yr in Army Air Corps and Infantry Intelligence. Married. Age 28. No disability. Available in fall. Salary open. W-337-409

SALES, service, writing, management, advertising or general marketing in rural electric field with manufacturer, processor, distributor, or consultant, anywhere in USA. Farm background. BS deg in business administration, 1947, The Citadel. MS deg in business administration, 1950, Wharton Graduate School. Thesis subject, "A Study of the American Farm Market for Electrical Equipment." Private investigator, Warner Bros. Pictures, 7 mo, 1943. Chemical analyst, du Pont, 4 mo, 1944. Time-study engineer, Dan River Mills, 12 mo, 1948-49. Sales manager, Jones Printing Co. 7 mo, 1949. Second Lieutenant, C.A.C. Res. Single. Age 22. No disability. Available now. Salary $3600. W-398-411

EXTENSION, teaching, or research in power and machinery with college or experiment station in East or Northeast. BS deg in agricultural engineering 1949, Pennsylvania State College. Farm background. One year with large retail farm implement distributor as farm division manager responsible for sales and service of complete line of farm equipment. War service in Navy 2½ yr. Single. Age 26. No disability. Available on reasonable notice. Salary open. W-414-412

Development, teaching, or management in power and machinery, farm structures, or soil and water field with private industry in USA or Canada. BS deg in agriculture with major in agricultural engineering, McGill University. Received A I C Scholarship and worked on master's degree (not yet completed) at University of British Columbia. Experience in maintenance and operation of earth-moving equipment on Alcan Highway, 2 yr. Assistant agricultural engineer for provincial government one year. Secretary-treasurer for Housing Committee 2 yr, including writing of several publications. Extension agricultural engineer in a western state, part of one year. War service in RCAF, aircrew, commissioned, 2 yr. Married. Age 35. No disability. Available now. Salary open. W-412-413

DESIGN, development, research, sales, or writing in power and machinery or soil and water field, with public service or private industry, preferably in Midwest or Northwest. Willing to travel. BS deg in agricultural engineering expected in August, University of Missouri. Farm background. Engineering aide (GS-4) in U. S. Soil Conservation Service. Surveying structure sites, designing control structures, and discussing conservation problems with farmers. War enlisted service in Army 20 mo. Married. Age 22. No disability other than vision, corrected by glasses. Available Sept. 1. Salary open. W-410-414

DESIGN, development, or research in farm structures or soil and water field with public service or private industry, preferably in Southwest or West Central State.. Willing to travel. BS deg in agricultural engineering 1950, Oklahoma A & M College. Farm background. One summer with Soil Conservation Service. War noncommissioned service in infantry. Single. Age 26. No disability. Available now. Salary $3000. W-417-415

New Bulletins

Twenty-fifth Annual Report of the Kansas Committee on the Relation of Electricity to Agriculture. Department of agricultural engineering, Kansas State College (Manhattan, November, 1949). In addition to administrative reports this 92-page mimeographed bulletin includes technical reports on commercial dehydrators, farm freezers, farm welders, clothes driers, and heat pump installations.

Terracing to Save Soil, by John L McKitrick. Circular 473, Agricultural Extension Division, University of Kentucky, (Lexington), July 1949. A guide on terracing practice for farmers.

Roller Crusher for Drying Hay, by J. W. White and W. Kalbfleisch. Experimental Farms Service, (Ottawa, Canada). Reprint from *Scientific Agriculture,* March 1950.